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RUSSIAN AND ENGLISH FIELD AND COAST GUNS.

A MOST valuable paper on the subject of "Russian Artillery in 1888," by Captain C. A. Court, of the Rifle Brigade, appears in the last number of the *Journal of the Royal United Service Institution*. At a time when public attention has been so conspicuously directed to the condition of the defenses of the United Kingdom, and particularly so in regard to the trustworthiness and completeness of our coast batteries and fortresses, such a paper will compel a more than ordinary interest, as it enables us to draw a comparison between the results which have been effected in the two several countries of Russia and Great Britain by the output of artillery scientific energy since the introduction of rifled guns. This "transition" period in the great Muscovite empire has been one of remarkable advance in the study and development of war *materiel*. It is, too, as the paper says, "coincident with an epoch when the reign of force was firmly established in Europe, and when the expansive force and vitality of a state began to reckon, not by its light and leading in peaceful arts, sciences, and industries, but in its power and ability to create the most complete, approved, and deadly engines of war for the future annihilation of its neighbors."

We give below engravings of the Russian light and heavy field guns, showing how materially they differ in construction from our own. In Figs. 1 and 1 A, the tube or lining is of Martin-Siemens steel, compressed by hydraulic machinery on the Whitworth system at a pressure of 90 atmospheres. The jacket, which is carried forward right to the muzzle of the gun, is constructed of puddled steel cast in a crucible, but not subjected to pressure; it contains the slot for the wedge block. The trunnion hoop is of compressed steel, and is heated before it is placed over the jacket. It is retained in its position by a ring, composed of two half rings and covered by another hoop. The tube is fitted into the jacket when cold, under a pressure of about 30 atmospheres, by an hydraulic press. It is rifled before this operation takes place, and is entirely finished, as also is the jacket, over which the trunnion coil has afterward to be fitted. Thus a worn out or damaged tube can be replaced with comparative ease; and another very important point is gained: "Alterations and improvements can readily be made in the tube and interior arrangements generally, without entailing as a necessary consequence the condemnation of a whole system of ordnance." But the fitting of all the several parts to one another must be accomplished with extraordinary nicety to admit of the gun being "assembled" when cold. This has not been attempted in our own gun factories. The breech mechanism is of the ordinary wedge and steel Broadwell ring pattern, and similar to a very considerable extent to that employed for the German field gun. Engravings are appended showing longitudinal and transverse elevations and sections of the same, Figs. 2 and 3. It is, of course, widely different from the system employed in our new 12 pounder, and not in any way comparable with it, we fully believe. Nothing could be more simple than the arrangement adopted in the British field gun for opening and closing the breech, and the obturator is of the most satisfactory character.

But what we desire particularly to draw attention to in the present paper is the very preponderating influence of coast and fortress artillery interests in the minds of military experts in Russia, as exhibited in the enormous development of this special class of guns. Our own condition in this respect is anything but sat-

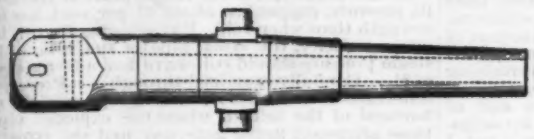


FIG. 1.—Russian Field Gun—Plan.

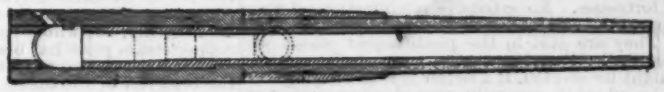


FIG. 1A.—Russian Field Gun—Construction.

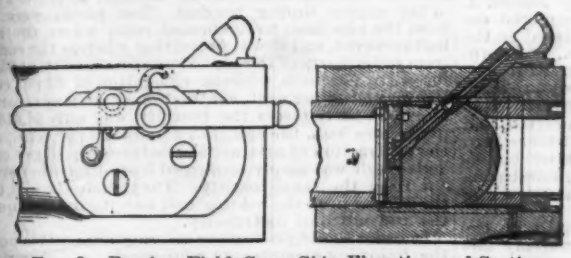
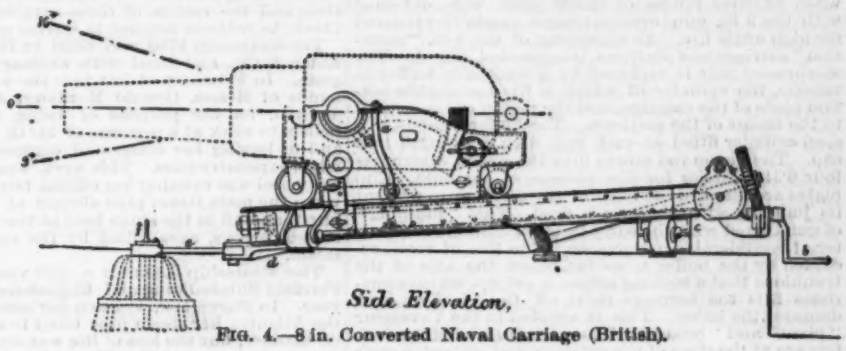


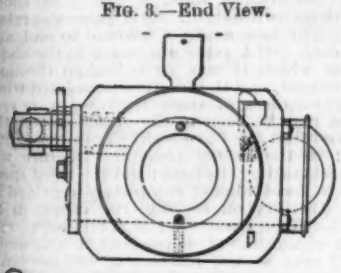
FIG. 2.—Russian Field Gun—Side Elevation and Section, Breech Mechanism.



Side Elevation.

FIG. 4.—6 in. Converted Naval Carriage (British).

FIG. 3.—End View.



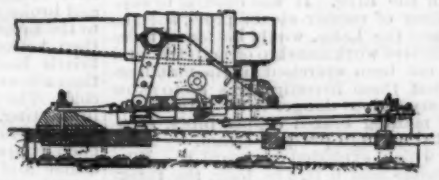


FIG. 5.—9 in. Russian Gun and Semenov Carriage.

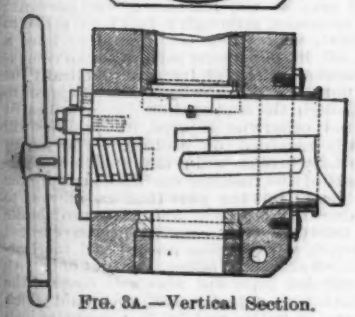


FIG. 3A.—Vertical Section.

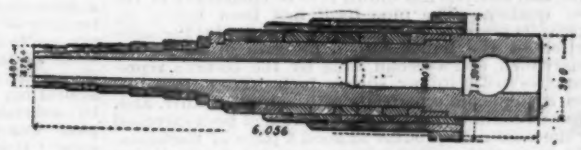


FIG. 7.—11 in. 43 ton Gun Construction.

FIG. 8.—Steel Howitzer Construction.

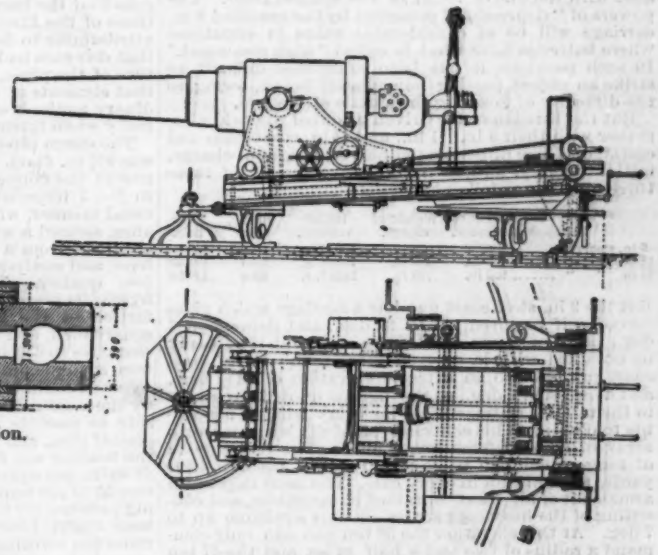


FIG. 6.—11 in. Russian Guns and Carriages.

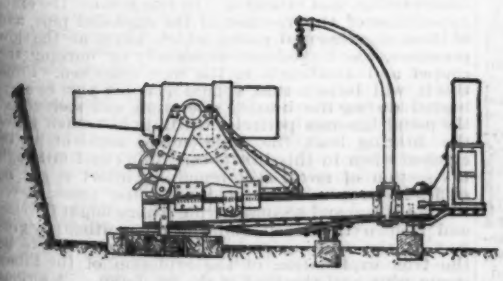


FIG. 8A.—9 in. Russian Steel Howitzer.

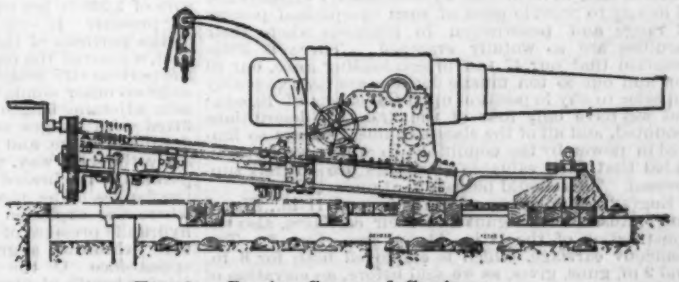


FIG. 6A.—Russian Guns and Carriages.

RUSSIAN FIELD AND COAST GUNS.

isfactory. We remarked in a recent paper in these columns that 920 heavy muzzle-loading guns were mounted in position at the various fortresses around the shores of the United Kingdom. But we omitted to note that effective fire at long ranges was precluded in the case of nearly the whole of these guns, owing to the impossibility of giving sufficient elevation to command an extensive radius. The carriages for British 9 in. and 10 in. guns for land service are so constructed as only to admit of an elevation of 10 deg. being given to them, and with this figure a range of only 5,000 yards is obtainable. The 38 ton guns of 12½ in. caliber are even worse off in this respect. They are all mounted in casemated batteries, and in the majority of instances only an elevation of 7 deg. is possible, owing to the contracted size of the casemate ports. This gives an extreme range to these batteries of only 4,500 yards, less than half of what, under usual circumstances, the gun itself is constructed to attain. Such a condition of things is intolerable, and the only wonder is that hitherto the fact should have escaped observation. It is true that a modification of the naval slides and carriages for the 8 in. R. M. L. gun has been effected, called an "elevating" carriage and platform, which admits of an elevation of 16 deg. being given to the weapon and a depression of 9 deg., thus creating an arc of 25 deg. altogether. But this will only be applied to the 8 in. muzzle loader cast off by the navy —it having been hitherto exclusively a naval gun—and which will be utilized to supplement the existing armament of fortresses. No extensive modification of this nature has taken place in the batteries around our coasts. They are still in the predicament which we have described. But the vast nature of the reform which might be effected, if a better system of elevation were to be adopted generally, was clearly manifested at Warden Point, in the Isle of Wight, the other day, when effective ranges of 10,000 yards were obtained with the 9 in. gun upon carriages specially prepared for high angle fire. An engraving of the 8 in. "elevation" carriage and platform is appended, Fig. 4. The compressor gear is replaced by a hydraulic buffer in tension, the cylinder of which is fixed along the bottom plate of the carriage, and the piston rod is secured to the breast of the platform. The buffer consists of a steel cylinder fitted at each end with a wrought iron cap. The piston rod screws into the piston, which has four 0·54 in. holes for the passage of the fluid. Clip plates are fitted to the front of the carriage to prevent its jumping when the gun is fired. This "jumping" of guns fitted with the early forms of carriage is a matter of considerable importance. The line of recoil occupied by the buffer is so far below the axis of the trunnions that a rocking action is set up, which sometimes lifts the carriage right off the platform and damages the latter. This is avoided in the Vavasseur "pivot" and "broadside" mountings, where the buffers are at the sides of the carriage, and almost coincident with the line of recoil of the weapon itself. The powers of "depression" possessed by the modified 8 in. carriage will be of considerable value in situations where batteries have what is called "high command." In such positions it has been sometimes difficult to strike an object passing immediately below, owing to the difficulty of lowering the muzzle of the gun.

But the Russians have driven us out of the field altogether with their 9 in., 11 in., and 14 in. coast guns and carriages. The projectiles employed, weight of charge, initial velocity, and actual effective ranges of these three guns are as follows:

	Weight of projectile.	Weight of charge.	Initial velocity.	Range, yds.	Elevation.
9 in. steel gun.....	248 lb.	58 lb.	1500 f. s.	6000	14° 4
11 in. " "	478 lb.	119 lb.	1500 f. s.	6000	12° 35'
14 in. " "	960 lb.	198 lb.	1476 f. s.	6000	14° 55'

But the 9 in. steel coast gun has a carriage which gives elevation if required up to 23 deg., and depression 7 deg.; hence a range of 10,000 yards could very easily be obtained with it, or even more. The 11 in. steel coast gun has also an extreme elevation of 14½ deg., and depression 6 deg., so the figures quoted for range in the tabular statement are far below what it is possible to obtain. This contrasts painfully with our own array of coast defense heavy guns. The very outside of range which can be squeezed out of them is 5,000 yards, and this not in every case. The most important armament of all—that contained in casemates, and consisting of the heaviest natures—is only available up to 7 deg. At this elevation the 38 ton gun can only command a radius of two and a half miles, and the 47 ton steel breech loader, two of which only are actually mounted, two and three-quarters miles. It seems, in point of fact, to be almost an unnecessary expenditure of money to provide guns of such exceptional powers of range and penetration in positions where their faculties are so wofully cramped. There is little question that our 47 ton breech-loading guns, our 80 ton and our 38 ton muzzle loaders are immeasurably superior to any in position upon the coasts of Russia; but we have only four of the first two descriptions mounted, and all of the classes enumerated are so limited in power by the conditions to which we have alluded that their valuable attributes are entirely suppressed. This should be seen to at once.

Engravings are given of the 9 in. and 11 in., Figs. 5 and 6, Russian coast guns and their carriages, also the construction of the 11 in. 43 ton gun, Fig. 7. The Semenov carriage, which is employed both for 8 in. and 9 in. guns, gives, as we said before, an elevation of 23 deg., and a corresponding power of range. The 11 in. carriage with hydraulic brakes uses glycerine in its cylinders. With howitzers also the Russians have made great advances. An engraving is given of the 9 in. steel howitzer, showing its constructive features, and also its appearance when mounted upon the carriage, Figs. 8 and 8 A, which presents several remarkable characteristics, being capable of elevation up to 40 deg. In 1886 an 11 in. howitzer of this description, and mounted upon a similar carriage, gave very good results in Russia. It was inclined at an angle of 35 deg., and fired a 600 lb. shell at a range of 7,500 yards, with lateral errors of only 15 ft. to 30 ft., and longitudinal errors from 63 ft. to 126 ft. Hence every shot fired by it would have descended upon the deck of a very small gunboat, and would have riddled the deck of an ironclad through and through. We have no weapon either in our siege or coast artillery which would give corresponding results, under the conditions, as to mounting, at present existing in our batteries. This surely is a grave reflection upon the most opulent and scientific nation in the world.

Before we close, we would venture to make one general remark upon the nature of our coast defenses. They are for the most part open batteries; these it is impossible to regard as other than death traps to the men working the guns. With all the modern appliances for firing powerful machine and quick-firing guns in the tops of battle ships, protected by steel shields which effectually secure the safety of the marine gunner, it would be a mere matter of ten or fifteen minutes' work to clear away the gun detachments from open batteries as one would mow down grass. We therefore strongly urge upon the war department the advisability of providing some shelter for the gunners in all cases where emplacements are not fitted with Moncrief disappearing gun carriages. It is of immense importance to instill confidence in the mind of the man who works the gun.—*The Engineer.*

COPPER STEAM PIPES FOR MODERN HIGH PRESSURE ENGINES.*

By W. PARKER.

As might have been expected, the disastrous explosion of the main steam pipe and consequent loss of life that occurred on board the royal mail steamer Elbe in September last, and a similar explosion on board the North German Lloyd's mail steamer Lahn, have led to investigations as to the cause of these accidents, and, further, the whole subject of the manufacture of copper steam pipes has been considered generally, and experiments carried out with the view of ascertaining the behavior of the different kinds of commercial copper under various conditions of treatment and at various temperatures. A summary of the investigations and the results of these experiments will not, I think, be without interest to marine engineers.

The steamship Elbe was built in 1870 by Messrs. J. Elder & Co., and fitted with ordinary compound engines. In February of last year she was placed in the hands of Messrs. Oswald Mordaunt & Co., of Southampton, for the purpose of being fitted with new boilers to work at a pressure of 150 lb. per square inch, and of having her compound engines converted into triple expansive ones. This work was completed, and the vessel was running her official trial in Stokes Bay, when the main steam pipe abreast of the after boilers burst, and all in the stoke hold at the time, numbering eleven persons, were killed by the sudden outrush of steam.

The steamship Lahn is a new vessel, built by the Fairfield Shipbuilding and Engineering Company last year. In March last, while on her second voyage across the Atlantic, her steam pipe burst in a somewhat similar manner, but the loss of life was less in this instance than in the case of the Elbe. It was natural to suppose that the bursting of copper steam pipes, such as those of the Elbe and the Lahn, would be found to be attributable to defective workmanship or material, and that due care had not been exercised in the manufacture of the pipes, but these investigations go to show that elements of very serious danger enter into the ordinary methods of making brazed copper pipes, especially when intended for high pressure steam.

The steam pipe which exploded on board the Elbe was 9⅝ in. diam. inside and 6 ft. 6 in. long, the thickness of the copper was 0·276 of an inch, corresponding to No. 2 imperial wire gauge. It was brazed in the usual manner, with a lapped joint, and, to all appearance, seemed a well made pipe. The copper had been obtained from a first class manufacturer in Birmingham, and analysis has shown it to be chemically of the best quality. The pipe itself had been tested by hydraulic pressure on two occasions—once for the satisfaction of the builders to a pressure of 300 lb. per square inch, and a second time by the owner's representative to 350 lb. per square inch. These tests had been sustained in a perfectly satisfactory manner, and, so far as could be judged, every care had been exercised by the makers to produce as good a piece of workmanship as possible. Test pieces were cut from the exploded pipe, and the copper away from the locality of the brazing was found to have an ultimate tenacity of 33,000 lb. per square inch, with an elongation before fracture of 38 per cent. in a length of 5 in, so that the bursting pressure for this pipe, in its cold state, should have been about 1,940 lb. per square inch, being thirteen times the working pressure, or, taking the actual thickness of the copper at the fracture as measured after the explosion, and which was found to be $\frac{1}{16}$ of an inch, the pipe should still have borne an ultimate pressure of 1,220 lb. per square inch, or 8·8 times the working pressure. In order to ascertain the actual strength of the portions of the pipe adjacent to the exploded part, a piece of the pipe about 30 in. long was cut from the portion still intact of the length which exploded, and two other similar pieces were prepared from the next adjoining length of pipe. These short pieces were fitted with flanges and tested to destruction by hydraulic pressure, and in each case the pipe burst in exactly the same way, viz., through the copper near and parallel to the brazed seam, commencing near to one of the flanges. The pieces taken from the same length where the explosion had occurred gave way under a hydraulic pressure of 780 lb. per square inch, the fracture exhibiting a granular and, in part, a discolored appearance. Of the two pieces cut from the next adjoining length of pipe, one burst at 600 lb. per square inch, with the same granular and partly discolored fracture as if the metal had been injured or partially cracked through during the operation of brazing, and the other burst at 1,140 lb. per square inch, the fracture being granular, but not discolored. This great diversity in the bursting pressures for pipes of the same dimensions and material and the similarity in the character and position of the fracture in each case, together with the fact that the pressure at which the strongest of these lengths burst was still not more than five-eighths of the calculated bursting pressure, seemed clearly to indicate that the material had been injured in the neighborhood of the seam by the operation of brazing.

Some very careful experiments to ascertain the effect of increased temperatures upon sheet copper were made by the Franklin Institute in America as long ago as 1837, when strips of copper were pulled asunder in a properly designed machine at temperatures ranging from 123° F. to 1,332° F., and, as will be seen by the following table, the falling off in strength as the temperatures increased was very considerable, until at 1,332° F., or a bright red heat, the tenacity was *nil*.

EXPERIMENTS MADE AT THE FRANKLIN INSTITUTE, AMERICA, IN CONNECTION WITH AN INVESTIGATION INTO THE STRENGTH OF BOILERS.

Temperature above 32° F.	Diminution of Strength.	Temperature above 32° F.	Diminution of Strength.
90°	0·0175	660°	0·3425
180°	0·0540	769°	0·4380
270°	0·0926	812°	0·4944
360°	0·1513	880°	0·5581
450°	0·2046	984°	0·6691
460°	0·2133	1000°	0·6741
513°	0·2446	1200°	0·8861
529°	0·2558	1300°	1·0000

These results were substantially corroborated by a series of experiments made by Dr. Kirk and myself after the Elbe explosion. From the table it will be seen that at 360° F., or the temperature of steam of 150 lb. pressure, copper has about 15 per cent less tensile strength than when cold. But, allowing for this falling off in tenacity, the steam pipe of the Elbe at 150 lb. steam pressure should still have had a factor of safety of 8½. Carefully examined through a microscope, the difference in the structure of the copper in the neighborhood of the brazing where the exploded pipe and those afterward tested gave way and the structure in that part of the pipe away from the brazing was very marked, and was clearly to be ascribed to the heating of the copper during brazing. Test pieces were cut from the pipe near to the brazed seam where the rent had occurred, and it was found that whereas the copper from other parts of the pipe showed a tenacity of 33,000 lb. per square inch, with an elongation of 38 per cent. in 5 in. and 59 per cent. contraction of area as recorded above, in these pieces the tenacity was only 24,418 lb. per square inch, the elongation only 4·6 per cent., and the contraction of area at the fracture only 13 per cent. This result was amply confirmed by testing other strips cut from the same locality. They each showed that the copper near the brazing had lost its ductile qualities and much of its tenacity.

In order to obtain further information on this point, the following experiments were made: (1) A strip of good copper was cut from a sheet and bent and broken cold. (2) A similar piece was raised to a heat above that necessary for brazing, when it became red short, and broke with its own weight. (3) A piece was raised to the same bright heat as No. 2, allowed to cool, and then broken cold. (4) A piece was raised to the above brittle heat, at which it was partly broken through, then allowed to cool, and the fracture completed when cold. The appearances of these fractures were very interesting, as may be seen in the specimens on the table. The first had the fibrous silky appearance of a good copper; in the second piece the fracture was coarse and blackened by the heat; but the third specimen seemed to have almost completely regained its tenacity and ductility on cooling, the copper in its normal state having a tenacity of 35,212 lb. per square inch, with an elongation of 40 per cent. in 5 in. and a contraction of area at the fracture of 39·9 per cent.; and the third specimen, although it had been raised to a blistering heat, was, when cold, found to have a tenacity of 31,337 lb. per square inch, with an elongation and contraction of area at fracture practically the same as the normal copper, which would appear to show that, although the copper should be over-heated in brazing, if not otherwise injured, its qualities will be substantially regained on cooling. The fourth piece was partially broken while hot, and the appearance of that part of the fracture was discolored by the action of the heat; but the part that was allowed to cool had its ductility restored, and afterward broke with a bright fracture. This experiment was repeated a number of times, with similar results, and the fractures corresponded exactly in appearance not only with that of the exploded pipe, but also with those of the other pipes which were experimented upon, and which burst at pressures of 600 lb. and 780 lb. per square inch respectively. The only difference in these fractures was the depth to which the partial crack, as shown by discoloration, had extended. In this manner the exact appearance of the fractures of the exploded pipe, and of those experimental pieces which burst at the low pressures, was reproduced artificially by burning the copper and treating it in the way described. From this it will be seen that, should a copper pipe be overheated during the brazing operation, and seeing that the metal becomes perfectly brittle at not much above the brazing heat, the pipe might accidentally be cracked when in this btittle condition; and although the section of metal still remaining intact might be sufficient to sustain the cold water test pressure, yet the hot steam and accompanying strains might develop and deepen the crack, and the pipe ultimately give way at the working pressure. This I consider to be the true explanation of the explosion of the Elbe's steam pipe, and also that of the SS. Lahn. A serious element of danger is thus shown to exist in the present practice of brazing large heavy copper pipes intended to be subjected to the high pressures now so common. It is generally admitted that welds or brazed joints in any material must possess certain elements of uncertainty, and the above experiments show this uncertainty to be greatly increased in the case of copper worked over a fire. How to eliminate these elements of danger becomes an important question. Various alternatives suggested themselves, as, for instance, that the copper might be worked cold and the joint made by a riveted seam, that brazed pipes might be served with wire or have strengthening bands fitted at short intervals (both of which systems I find are now resorted to), or that steel pipes might be used, the seam being riveted.

MANUFACTURE OF COPPER PIPES BY ELECTRICITY.

While these points were under consideration, I had brought to my notice by Mr. W. Elmore a method of

*Paper read by Mr. W. Parker, at the meeting of the Institution of Naval Architects, Glasgow, July 25, 1888.

COPPER STEAM PIPES FOR HIGH PRESSURE ENGINES.

TABLE I.—DEPOSITED COPPER.

Marks on Specimen.	Dimensions in Inches. Breadth.	Thickness	Area.	Tensile strain in tons. Total.	Per. sq. in.	Elongation, per cent. In 8 in.	In 5 in.	Contraction of area, per cent.	Remarks.
A 1	2·0	0·175	0·351	8·36	23·80	13·7	20·0	73	Electro-deposited copper cut circumferentially from the pipe.
A 2	2·0	0·18	0·36	8·35	23·22	13·0	17·5	68½	
A 5	1·0	0·18	0·18	4·32	24·00	12·9	16·0	82	Cut longitudinally from the pipe.
A 6	1·0	0·18	0·18	4·27	23·70	13·2	13·2	71	

TABLE II.—SOLID DRAWN COPPER.

B 1	2·0	0·195	0·39	8·0	20·5	3·75	7·1	13·8	Solid drawn copper cut circumferentially from the pipe.
B 2	2·0	0·195	0·39	8·0	2··5	3·75	6·0	12·8	
B 5	1·0	0·190	0·19	3·8	20·0	2·90	7·0	43·6	Cut longitudinally from the pipe.
B 6	1·0	0·190	0·19	3·8	20·0	3·10	7·0	36·8	

TABLE III.—ROLLED SHEET COPPER

C 1	2·0	0·265	0·53	7·46	14·0	45·0	30·0	44·5	Rolled sheet copper cut in the direction in which it was rolled.
C 2	2·0	0·265	0·53	7·46	14·0	44·0	30·0	45·5	
C 5	1·0	0·265	0·265	3·72	14·0	45·0	35·5	31·0	Cut across the direction in which it was rolled.
C 6	1·0	0·265	0·265	3·71	14·0	42·0	33·5	31·5	

TABLE IV.—TABLE SHOWING EFFECT OF TEMPERATURE IN DIFFERENT DESCRIPTIONS OF COPPER.

Mark on Specimen.	Thickness	Breadth.	Area.	Total load in tons.	Tons per square inch.	Percentage of Loss.	Temperature in degrees F.	Remarks.
....	....	....	....	....	....	....	60°	Cold.
P 1	0·237	2·0	0·474	6·80	14·33	....	60°	
P 2	0·237	2·0	0·474	5·05	10·66	26½	390°	Rolled sheet copper.
P 3	0·237	2·0	0·474	5·00	10·55	26½	390°	
....	....	....	....	....	....	....	60°	Cold.
S 1	0·192	2·0	0·384	7·70	20·0	....	60°	
S 2	0·195	2·0	0·390	5·55	14·23	25·2	390°	Solid drawn copper.
S 3	0·194	2·0	0·388	6·10	15·7	....	390°	
....	....	....	....	....	24·0	....	60°	Cold.
T 1	0·179	2·0	0·358	5·50	15·35	....	390°	
T 2	0·179	2·0	0·358	5·23	14·65	....	390°	Electro-deposited copper.
T 3	0·179	2·0	0·358	5·45	15·2	....	390°	

making copper pipes of any required diameter, length, or thickness by electro-deposition, and I was instructed by the Committee of Lloyd's Register to proceed to Mr. Elmore's works and witness the operation of making these pipes, with a view to reporting thereon for the information of the committee. The process is briefly as follows: A mandrel is surrounded by ordinary unrefined Chili bars arranged upon strong supporting frames in a depositing tank of sulphate of copper, and the copper is dissolved or decomposed, as will hereafter be explained, and is deposited in the form of pure copper on the revolving mandrel, leaving the copper in the form of a shell or pipe of any thickness required, fitting closely to the mandrel. When the required thickness has been deposited, the pipe and mandrel are exposed to the action of hot air or steam, then the copper expanding more than the iron admits of the mandrel being drawn, leaving the copper in the form of a pipe, without a seam, perfectly round and true both internally and externally; or the pipe may be expanded or made larger by rolling or other mechanical means, and then the mandrel withdrawn. The deposition of copper by electricity is not at all new. It has been in use for years for electrotyping purposes, and for separating copper from its impurities, and particularly for extracting gold and silver. But copper thus refined is wanting in cohesive properties, and without some means of increasing its density, which would give to it, at the same time, both tenacity and ductility, it would in such a form be useless for mechanical purposes, and the ingenious manner in which this difficulty is overcome by the present process constitutes its most important feature. A burnisher or planisher, composed of a small square piece of agate, being the hardest and smoothest substance suitable and available, is supported upon proper arms and levers, and the agate is allowed to press lightly upon the surface of the copper on the revolving mandrel. The burnisher is caused to traverse from end to end of the mandrel by means of a leading screw at any required speed. After it has traversed the whole length of the mandrel, it is automatically reversed, and commences its journey backward. The speed of the revolving mandrel and the speed of the traversing burnisher is so adjusted or arranged that the whole surface of the copper is acted upon by the burnisher, the result being that every thin film of copper deposited upon the mandrel must be separately acted upon, burnished, and compressed into a dense and cohesive sheet of pure copper possessing a great amount of tenacity and ductility, as will be seen from the results of the experiments and tests which I have made, and which will be referred to further on. The impurities or dross fall to the bottom of the tank in the form of mud, and when washed, dried, and smelted in a crucible, the gold, silver, etc., contained therein can be easily separated. In fact, during the operation of refining copper from the rough Chili bars, the finished article is automatically produced in the form of a pipe, and all the impurities are extracted and can be collected. While I was present at the works of Mr. Elmore, the patentee of this process, four pipes were made. The mandrels had been revolving in the baths for about 170 hours, and the copper in this length of time had reached a thickness of 0·198 in. The pipes were taken off the mandrels in my presence, and the ends of the pipes cut off, so as to present a portion of the pipes acted upon by the burnisher. The remaining portion, or rough ends, shows the nodules, or rough copper not acted upon by the burnisher, which is in a completely brittle condition. This will be seen by the specimen. It is well known that the structure of ordinary electro-deposited copper is purely crystalline, and easily disruptured under stress. The adjoining faces of the crystals, of which the whole mass is composed, appear under the microscope to be separated from each other, and have very slight cohesive power. In order to show the effect of the burnisher upon the material, I have had the structure of specimens of pieces of copper magnified under a microscope and then photographed. No. 1 photo is taken from an ordinary piece of cast copper. No. 2 is taken from a rolled bar of copper. The difference in these two structures is very perceptible, and plainly shows the effect of work in the shape of rolling. No. 3 shows the structure of a piece of ordinary deposited copper not burnished, and No. 4 shows the structure of a piece of copper one-third unburnished and two-thirds burnished. From these photos it can plainly be seen to what extent the crystals are reduced in size, and the cohesive power of the material increased.

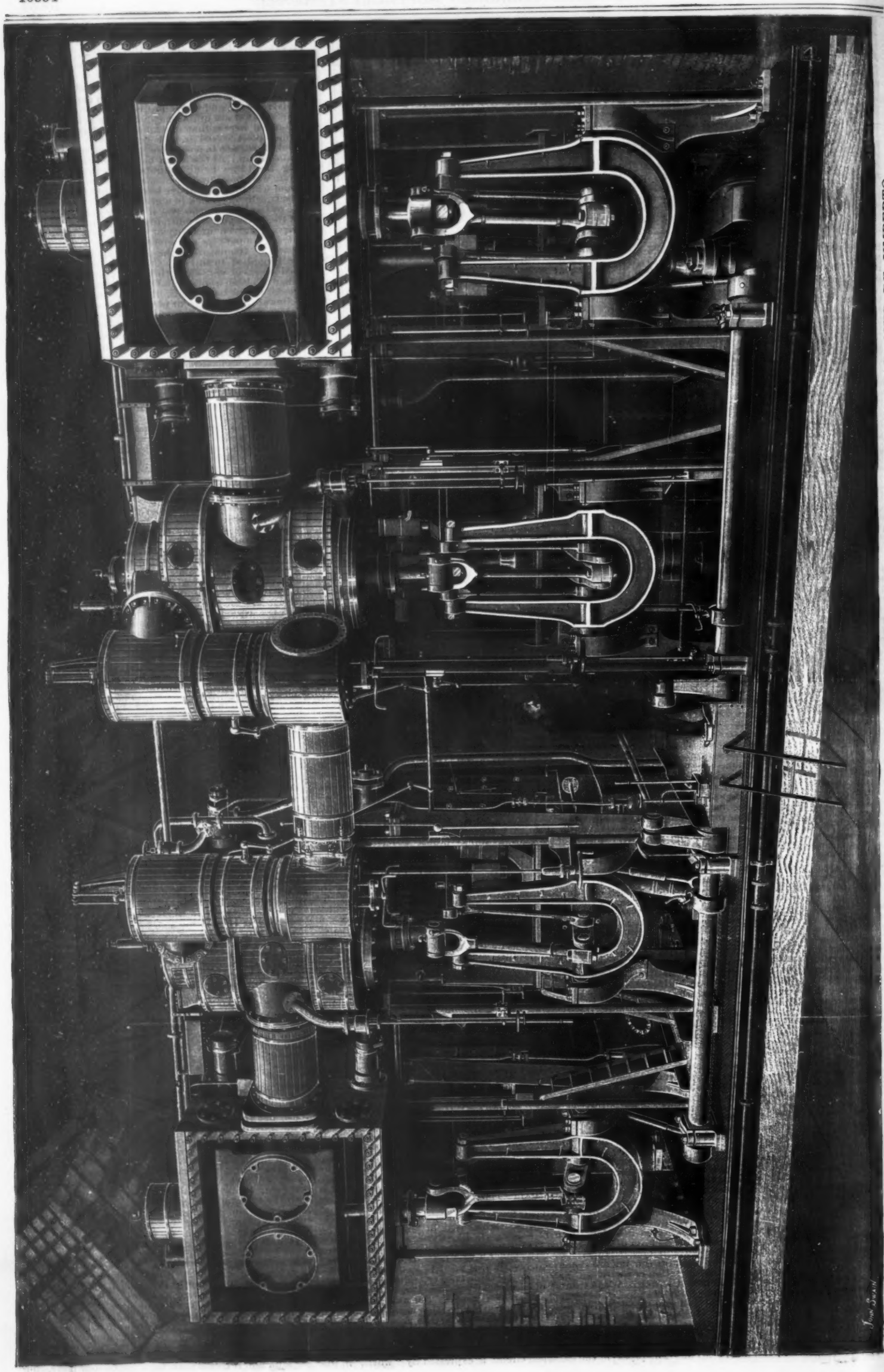
To describe more in detail how the decomposition of the unrefined copper is effected, and how the deposit takes place, I may state that the unrefined Chili bars are cast into slabs of the required length of the pipe, and these are arranged longitudinally in a wooden tank, in such a manner that the faces of the slabs are approximately at equal distances from, and parallel with, the surface of the cylindrical mandrel, both at its sides and underneath it, leaving the upper side open for the burnisher to travel over. The mandrel is fitted with a properly insulated spindle, running in insulated bearings, and driven by suitable wheel gearing, etc. The whole of this arrangement is immersed, as before stated, in a bath of sulphate of copper. The mandrel forms what is termed the cathode, and the copper bars the anode, of the electric circuit. The cathode is connected with the negative pole of an ordinary dynamo machine, and the anode with the positive pole. When the dynamo is set in motion, an electric current passes through the solution, and the following chemical changes take place. The sulphate of copper is decomposed, and the sulphuric acid is transmitted to the anode, there to attack and dissolve or combine with a quantity of copper equal to that which has been liberated or deposited upon the cathode. The electric terms used in this matter of the deposition of copper are like those for electro-plating and electro-typing, and it may be as well to describe them here. (1) The terms "cathode" and "anode" are synonymous with the positive and negative poles of an electric or galvanic battery. Then, to measure the volume of electricity passed between these points, the term "amperes" is used as the unit, like feet or cubic feet for measuring in the usual mechanical sense. (2) Then, for expressing the force with which the volume of electricity is propelled, the term "volt" is used as the unit. (3) The resistance opposed to the electricity is measured by "ohms." (4) The work done in the electrical circuit is expressed by "watts," in the same way that in a steam engine the power develop is expressed by h.p. To put this shortly—

1 ampere × 1 volt = 1 watt.
1 watt × 746 = 1 e.h.p.

These are the electrical terms employed by common consent in all European languages in connection with this science, and there are certain facts in relation thereto that are quite accepted. The principal one to be noted here is that one ampere of electrical current will deposit ·005084 gr. of copper per second per square foot of surface in a suitable bath and under fair circumstances. At the time I had the pleasure of witnessing the tubes being manufactured, the amperes and volts were measured by Siemens standard instruments, from which, on the above basis, the quantity of copper electrically deposited in a given number of hours could be estimated. In this way it was easy enough to judge of the horse power transmitted through the dynamo to deposit a given quantity of copper or a given thickness of copper pipe of a given diameter. As to quality, it was by the nature of the process almost bound to be uniform, but in this respect the photos of the magnified pieces of copper, both before and after the burnisher has been applied, and the mechanical tests I have made, are the best proofs. I may describe the latter as follows: Two of the four pipes I witnessed being manufactured I brought to London. One of these pipes I had fitted with strong flanges properly secured in an apparatus specially made for the purpose and tested to destruction. The other pipe I had cut into two pieces, and one of these pieces, marked A, is on the table for inspection. The other piece was cut and flattened out into a sheet, from which six test pieces were cut and prepared for making tensile tests. I also obtained from Messrs. J. Wilkes & Sons, of Birmingham, two solid drawn copper pipes of similar dimensions, and had them cut and tested in like manner. The piece marked B is cut from one of these pipes. In addition to these pipes I obtained from Messrs. Clelland & Thorburn, the well known coppersmiths, of Glasgow, a brazed pipe of the same dimensions, made specially for my experiments, which was also tested to destruction, together with a sheet of best rolled copper, so that corresponding test pieces could be made to those made from the electro-deposited pipe and the solid drawn pipe. The results of these mechanical experiments are most interesting. Pipe A, electro-deposited, stood a pressure of 3,450 lb. per square inch before it burst. The material stretched and the pipe expanded uniformly until the copper was reduced in thickness from $\frac{1}{5}$ in. to $\frac{1}{17}$ in. Pipe B, solid drawn, stood a pressure of 2,200 lb. per square inch. It also expanded, but not with the same uniform character as pipe A. Pipe C, brazed from sheet copper, also stood a pressure of 2,200 lb. per square inch, and burst, as all brazed pipes do, near the line of brazing.

The tensile strength and ductility of the copper cut from pipe A is given in table I.; the tensile strength and ductility of the copper cut from pipe B is given in table II.; and the tensile strength and ductility of copper cut from sheet copper, such as would be supplied for making pipe C, is given in table III. It will be seen from these tables that the tenacity in the normal state of these three descriptions of copper, the electro-deposited, the solid drawn, and the rolled sheet, are 23¾, 20¼, and 14 tons per square inch respectively. The very superior ductility of the pure electro-deposited copper is clearly shown by the manner of breaking, the elongation being chiefly confined to the neighborhood of the fracture, and whereas the contraction of area at the fracture in the solid drawn copper is 12·8 per cent., and in the sheet copper 45 per cent., in the deposited copper it averages 72 per cent. The tenacities shown by the test pieces are confirmed by the pressures at which the electro-deposited and solid drawn pipes burst under hydraulic pressure, and, as before stated, the uniformity of the deposited material is very conspicuous. In order to ascertain how deposited copper behaves as compared with solid drawn and ordinary sheet copper, and how its strength and ductile properties are affected by the action of heat, such as is contained in steam pressures that are now common, I have had a series of experiments made, the results of which are given in table IV.

The specimens were immersed in an oil bath while they were in the testing machine, the temperature of the oil being maintained by a gas flame; and by this means the specimens were pulled asunder at the temperatures given, which correspond with the temperature of steam at 200 lb. pressure. The results of these experiments are embodied in the preceding table, and are very interesting. The electro-deposited copper, it will be seen, as well as the solid drawn copper, stood about 15 tons per square inch, while cold rolled sheet copper broke at about 10¼ tons, at the temperature of 390° F. Comparing these tests with the interesting series made by Dr. Kirk at Lancefield, to which I have before referred, and published in *Engineering* in December, 1887, I find there were twenty-three specimens of copper plates tested at the same temperature, viz., 390° F. Some of these were cut across brazed joints, and others clear of the brazing. Of the nine samples which had been cut across the brazed joint, the mean tensile strength per square inch was 10·53 tons; but they varied in strength from 8·50 tons up to 12·32 tons, or about 40 per cent.—say 20 per cent. above and 20 per cent. below the average. The fourteen samples that were cut clear of the brazing broke with a mean tensile strength of 11·81 tons per square inch, the variation ranging from 10·19 tons to 13 tons per square inch, or from about 10 per cent. above to 10 per cent. below the average. Similarly comparing with the experiments made by me at the time of the Elbe explosion, the mean of four samples of sheet copper, at temperatures varying from 300° F. to 370° F., was 9·93 tons. Other experiments also go to show that ordinary sheet copper cannot be accorded a breaking strain of more than about 10 tons per square inch at the temperatures of high pressure steam, apart from the danger and uncertainty arising from brazing, which was so disastrously exemplified in the case of the Elbe and also the 88. Lahn. In the case of the electro-deposited copper, as also in solid drawn copper pipes, these experiments indicate a breaking strain at these temperatures of about 15 tons per square inch, or an increase of 50 per cent., and an absolute freedom from the dangers of brazing. This is a step in advance for which I am sure marine engineers will be grateful, and it comes none too soon, for our increasing



TWENTY THOUSAND HORSE POWER COMPOUND ENGINES OF THE ITALIAN TWIN SCREW WAR SHIP RE UMBERTO.

high pressures have here discovered a weakness and danger that was bound to cause anxiety. I find solid drawn pipes are now being made of larger diameter than hitherto, and I am not aware what the limit of their process of manufacture can go to; at any rate, there is no limit to which the diameters of the electro-deposited pipes can be made. Many other advantages are claimed for these electro-deposited pipes which I have not investigated; but so far as steam pipes are concerned, it is obvious that absolute uniformity of density, thickness, and tensile strength, and true circular section (all of which are important qualities), can be obtained. It is also established that copper deposited under a burnisher can be varied in tensile strength from the ordinary granular form to a material having high tenacity, and as it obviates the necessity for the steam pipes being put into the fire for brazing purposes, the strength and safety at high steam temperatures may be still further increased, and if so, we shall, I am sure, be further gratified.

I cannot conclude this paper, which I hope may not be without interest to the members of this institution and to others engaged in the manufacture and use of copper pipes, without expressing my thanks to Messrs. Maudslay, Sons & Field, for the great assistance they have been to me in carrying out a number of experiments, notably the bursting of the pipes, for which special appliances had to be devised, as also for the experiments at high temperatures. My thanks are also due to the Leeds Forge Company, who placed their testing machines at my disposal, and others who supplied me with copper and the necessary assistance and appliances for conducting these investigations.

ENGINES OF THE RE UMBERTO.

OUR engraving, prepared by the *Engineer*, from one of the largest photographs of steam machinery ever taken, shows one set of the twin screw engines of the great Italian war ship Re Umberto, as they stood in Messrs. Maudslay & Field's erecting shop. These engines will indicate 10,000 horse power on each screw. The engines are fitted with Joy's valve gear, and the low pressure valve chest lids are off, showing the slide valves inside.

The Re Umberto is one of three ships of nearly similar type, and is being built at Castelamare; she is 400 ft. long, 75 ft. beam, and displacing 13,251 tons, will draw 28 ft. 6 in. She is intended to steam at 18 knots; she will carry four 110 ton guns in barbettes.

MECHANICALLY PROPELLED BOATS.

A MECHANICALLY propelled lifeboat that would give the maximum result, and fully utilize the labor expended in rowing, has long been a desideratum, the disadvantages of a boat rowed by oars being both numerous and serious. In the first place, the oarsmen rowing cannot see where they are going, having their backs to the bows of the boat. They cannot always see if they are going next on the crest of a wave or in the trough of the sea. They cannot well ship oars or prepare for accident if a green sea or a big wave is about to strike them. In present lifeboats fully two-thirds of the oars when rowing in a rough sea are constantly out of the water, and a stroke is only obtained when the rowers can catch the water. Thus only one-third of the power on board is utilized in propelling the boat. The long sweep of the oars is an exhausting and feeble effort to face a gale, often necessitating a steam tug to take a lifeboat ont under these circumstances, or else she must go well to windward and drop or drift down to a wreck, which if the men fail to fetch, the boat is often carried away and hours are expended in working back or waiting for a tide. To obviate all this, Mrs. A. M. Wood, of 13 Delahay Street, Westminster, has designed a means of propelling a boat so that all the work expended is fully utilized by the floats in the water, and no matter how the boat may pitch or roll, so long as even only one float is in the water, it takes up all the energy and motion of the rowers, so that no expenditure of work is lost.

The rowers are always facing the bows of the boat and the object they are rowing to. The cranks or levers are all worked inside the boat, giving the men a secure hold on board. This is accomplished in the manner shown at Fig. 1 of our engravings, herewith. The boat is constructed on special lines, giving great stability and buoyancy, with hooded ends and chambers, to render the boat instantly self-righting.

On either side of the boat are five small paddle wheels with radial floats geared all on to one shaft, which is worked by foot treadles and hand levers, so that every man is able to continuously exert his power in propelling the boat, and when any of the wheels are out of the water, owing to the pitching or rolling of the boat, those in the water get the full benefit of the power of the crank: racing or slip being thus impossible, and a steady, continuous forward motion maintained. The sailors, while propelling the boat, will have additional safety and security against being washed overboard, having at all times a good hold on the levers fitted on board, which will give them a firm seat and holding. As the simple moving of the crank propels the boat, it is obvious that skilled labor is not required, and the lifeboat can be manned by any one, thus saving the labor and delay in mustering a skilled crew; and when persons are rescued from a wreck, all in the boat can assist in working it, and thus increased power be obtained. The paddles or oars can also be instantly reversed for the purpose of turning or backing.

It is also held that the boat can be brought close up to a wreck, as no space is required for the sweep of the oars, while the sponson and paddle wheel casing add to the beam of the boat, giving great stability and protection. A woodite bolster or rubbing piece runs from stem to stern, to prevent injury by collison or bumping. The same mechanical arrangement will also work oars (see Fig. 2), twin screw propellers, or paddle wheels. In some cases a reservoir of compressed air is placed in the center of the boat, and can be used for driving the machinery when desired. Oars, also sails, are provided for, and can be used if desired.

Mrs. Wood's triple torpedo boat is shown at Fig. 3. The object of this novel form of boat is to insure a triple security in case of accident or injury. Being constructed in three separate sections, each fully equipped and armed, securely attached to each other, they form one long boat, which by a simple mechanical arrangement can instantaneously be disconnected, forming three boats. In the event of injury during action, any one of the sections can thus be abandoned, leaving the remaining portion a double ship, while this can again be divided to form two separate vessels. Each being furnished with steam power, increased capability of maneuvering is obtained. While cruising, the foremost section only would be under steam, thus reserving the coal, but when going into action, each section would get up steam. Mrs. Wood has also designed a triple war or passenger ship (Fig. 4), the main object of which is safety, where so many lives are depending on the security of the ship. Mrs. A. M. Wood claims for this invention triple security and privacy, and many other advantages over existing ships. Should collision or accident occur to any part of the boat, the vessel so injured can be instantly detached, and the lives of the passengers secured by the accompanying ships, by means of a flying bridge from each vessel to the other. All the boats are fully equipped, provisioned, coaled, and provided with everything necessary for the passage.—*Iron*.

FIG. 1.

FIG. 2.

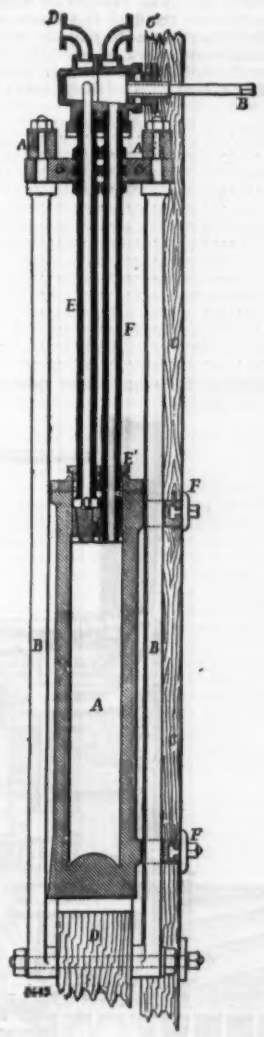
FIG. 3.

FIG. 4.

MECHANICALLY PROPELLED BOATS.

DOUBLE ACTION STEAM PILE DRIVER.

THE double action steam pile driver which we illustrate below is constructed by the Southgate Engineering Company, Limited, of New Southgate. It is carried by two rods, B, which are bolted together and to the pile at D. The whole pile driver moves with the pile, and is guided in its descent by the frame, C. The monkey is the steam cylinder, A; it rises and falls over the two hollow piston rods, E F, which are stationary in relation to the cylinder. The piston rods also constitute the steam passages, the left hand rod, E, leading to the space above the piston, and the other to the space below it. Steam for lifting the monkey is admitted through the former rod, and also exhausted by it. Steam for giving impetus to the downward stroke of the monkey is admitted through the piston rod, F. The admission and exhaustion is controlled by the three-way cock, B, which is so constructed that by shifting a pin the part of the plug which controls



the steam to the piston rod, F, can be made stationary. The monkey then becomes single acting. The piston rods are made of steel, bored up, with the collars turned out of the solid. The gland bushes are made in halves to permit of this.

The advantages claimed for the apparatus are that the flexible steam pipe is practically at rest, and does not wear out by constant reciprocation, and that there is no opening in the bottom of the monkey for water to escape through on to the pile.—*Engineering*.

EFFICIENCY OF PLANT.

By DR VOLSON WOOD, Professor of Engineering in Stevens Institute.

IT is interesting to note the gradual increase in the efficiency of steam plants. This improvement is due chiefly to the increase of efficiency in the engine, since the efficiency of the boiler is little, if any, better than it was many years ago. It is a popular statement that the steam engine utilizes only one-tenth of the heat of the fuel and that nine-tenths is wasted; and science is frequently censured for not devising more economical methods of saving heat, while science disclaims any responsibility in the matter. Science has long since pointed out the law according to which a greater per cent. of the heat may be utilized in an engine, and has turned the question over to art to devise the methods. Carnot showed that the maximum efficiency of a heat engine was directly as the difference of temperature of the refrigerator and furnace; or as the temperature of the source and the lowest temperature at which the heat was rejected. It remained for Sir William Thomson to find the exact expression for the maximum efficiency of any heat engine; or, in other words, the efficiency of *a perfect elementary* heat engine. The form of the expression was also deduced analytically by Rankine. The well-known form is—

$$E = \frac{T_1 - T_2}{T_1}$$

in which T_1 is the temperature from the absolute zero of a perfect gas thermometer at which heat is supplied to the engine, and T_2 that at which it is rejected. T_1 cannot exceed the temperature of the source or the boiler, nor T_2 be less than the lowest temperature of surrounding objects, that is, of the condenser. The

most perfect engine ever made falls considerably short of this value, but the law indicates clearly the direction in which improvements in the use of the engine must be made in order to secure increased efficiency. Since the refrigerator cannot be made much, if any, colder in practice than it has been, the improvement must come from using steam of higher temperatures and in perfecting the action of the engine. The absolute zero is so far below the temperature of melting ice, and the practical difficulties of using steam at *very* high temperatures render it practically impossible to transform into mechanical work more than a comparatively small fraction of the heat put into an engine. It has been asserted that steam at 300 pounds pressure to the square inch cuts the valve seat, and especially the edges of the ports, so rapidly as to make its use impracticable on this account alone. Advance cannot be made in one direction only; all the elements involved in the problem must be improved before a great advance can be made in any one. Provisions against leakage, weakness of any part, and excessive wear must all be provided for. The process by which the present pressures have been reached has been gradual. It is now quite common to use 160 pounds, and even this has been passed in some cases in everyday practice. This growth is well exhibited in the following table, taken from *Scribner's Magazine* of May, 1887:

Year.	Pounds.
1825	2 to 3
1830	5
1835	8
1840	10
1845	14
1850	21
1855	25
1860	30
1865	40
1870	50
1875	60
1880	70
1882	80
1886	150 to 160

It is impossible to assign exact values for the pressures used during any particular time, still the above values are probably approximately correct, and therefore show an approximate law of increase.

If steam be admitted into the cylinder at the initial pressure of 160 pounds, in which case the pressure in the boiler will be about 170 pounds, and the back pressure 2 pounds, we find from a table of saturated steam that the initial temperature of the steam will be 363° F. and the lowest 126° F.; and the engine will work between these temperatures, and hence, according to the above formula, the efficiency cannot exceed—

$$E=\frac{363-126}{363+460}=0{\cdot}285$$

or 28½ per cent. of the entire energy of the heat in the steam. No possible arrangement of parts, nor mode of construction, nor choice of material for the cylinder, nor management of the engine, could produce an efficiency greater than this, for the limits assigned. This is *the second law of thermo-dynamics*, stated in finite terms.

In practice no use is made of this formula in determining the actual efficiency of an engine or of a plant; but the work actually done is determined either from an actual indicator card or friction brake, and the fuel used is measured. Knowing the thermal equivalent of the fuel, the efficiency may be determined at once.

The following is an example of a remarkably efficient plant. In a copy of *Industries* for 1887 is a report in regard to the SS. Ohio, of the International Steamship Co. It had a gross tonnage of 3,350 tons, and a company agreed to put in a set of triple expansion engines aggregating 2,100 horse power, guaranteeing that the coal consumption should not exceed 1·25 pounds per indicated horse power per hour. The cylinders were 31 in., 46 in., 72 in., and 51 in. stroke. On a trial trip the actual coal consumption was 1·23 pounds per horse power per hour.

The calorific power of the coal is not given, but assuming that on such a trial the best coal would be used, we will assume its thermal equivalent as 15,000 heat units. Ordinary coal in the market often falls below 12,000 heat units per pound. The 1·23 pounds of coal would contain 1·23×15,000=18,450 heat units, which reduced to foot pounds gives 18,450×778=14,354,000 foot pounds. This developed one horse power per hour, or 33,000×60=1,980,000 foot pounds; hence, the efficiency would be—

$$E=\frac{1,980,000}{14,354,000}=0{\cdot}138$$

which is less than 14 per cent. of the heat energy of the coal.

If the heat of combustion of the coal were 12,000 heat units, the efficiency would be—

$$E=\frac{1,980,000}{1{\cdot}23\times778\times12,000}=0{\cdot}164 \text{ nearly,}$$

or less than 16½ per cent.

It is a good boiler that develops an efficiency of 70 per cent. As this was a trial trip, the boilers were probably in excellent condition, and if we assume that the efficiency of the furnace, boilers, and steam connections between the boiler and steam chest of the engine had an efficiency of 0·70, the efficiency of the engine alone would be in the former case—

$$0{\cdot}138+0{\cdot}70=0{\cdot}197$$

or nearly 20 per cent., and for the latter case—

$$0{\cdot}164+0{\cdot}70=0{\cdot}234$$

or more than 23 per cent.

The latter is probably too high and the former may be too low. Taking the mean of these as a more probable value, we have:

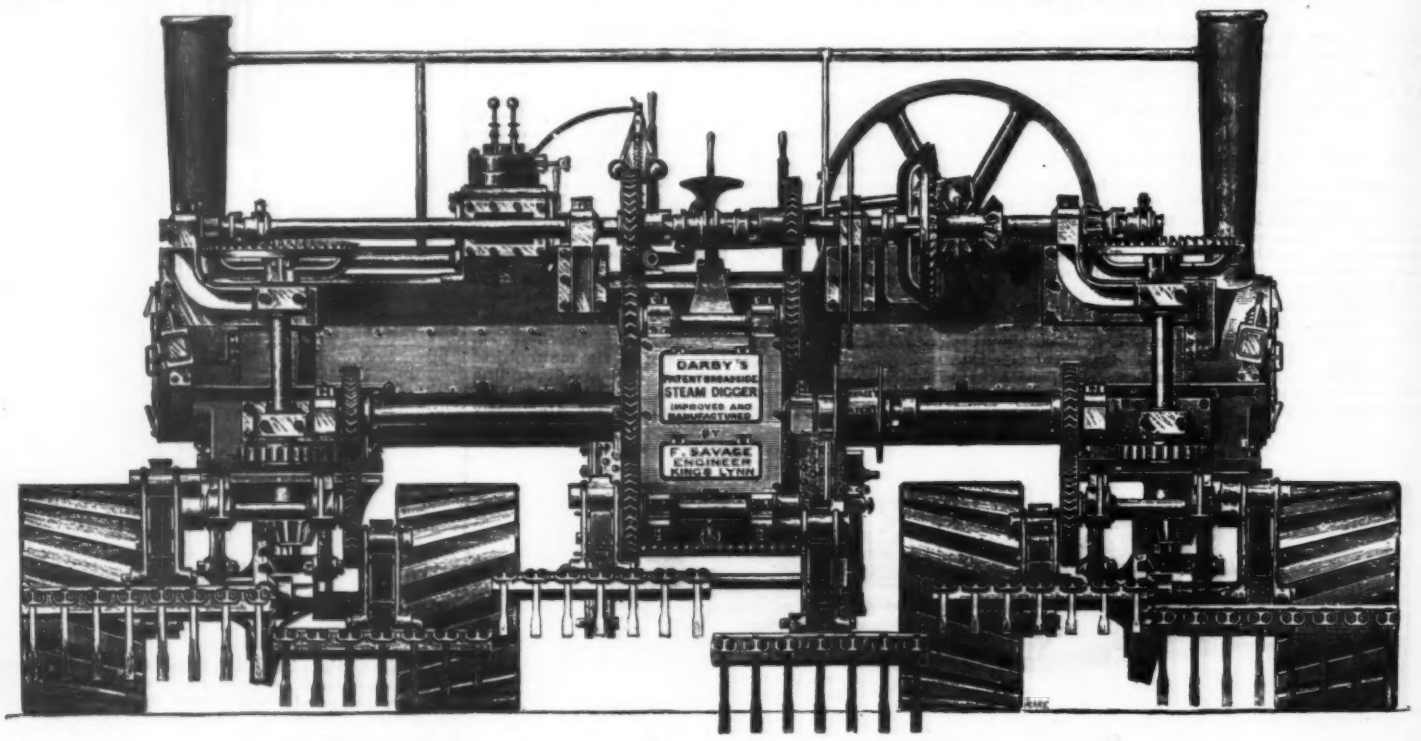
Efficiency of plant, 15 per cent.
Efficiency of engine, 21½ per cent.
Efficiency of boiler, 70 per cent.

If the heat put into the engine could be worked in a perfect elementary heat engine between the temperatures 363° F. and 126° F., 28½ per cent. of the total heat would be transmitted into mechanical work, as shown above; hence the engine above considered utilizes—

$$\frac{215}{285}=0{\cdot}747$$

or nearly 75 per cent. as much as would be utilized by a perfect elementary heat engine.

It is necessary to know more about the conditions of the trial than is known by the writer, in order to judge whether the exceptionally high efficiency here reported could be depended upon for continual service. It is to be presumed, on the one hand, that the owners of the ship would insist upon a trial that would be a fair test of the capacity and economy of the plant, and, on the other hand, there are many ways by which an expert could make the result appear too favorable to the contractors. But it is agreeable to believe that steam plants are now built whose efficiency may be 14 per cent., and engines whose efficiency is 20 per cent.



THE DARBY BROADSIDE STEAM DIGGER.

THE DARBY BROADSIDE STEAM DIGGER.

THE Darby steam digger has now been before the agricultural world for some years and we have watched its gradual development with interest. We have also seen it do good work under trying circumstances in its earlier stages. It distinguished itself at the Royal Show at Carlisle in 1880, since which time it has been taken in hand by Mr. F. Savage, of King's Lynn, and under his supervision it bids fair to become a valuable implement of tillage. The latest form of this digger was shown in operation in a field about two miles from the show grounds at Nottingham recently, where it was successfully worked, and received the approval of many practical men. This steam digger, which we illustrate, is a bold departure from every existing system of cultivating the land by steam power. It has two distinct motions, one in traveling on the road, which it does in the same way as an ordinary traction engine, while the other (which is the peculiar feature of the Darby digger) is a sidewise motion when traveling over the field to be dug. By means of an ingenious arrangement the wheels are capable of being turned underneath the boiler, so as to revolve at right angles to the length of the boiler. The digger is supported in this position by a steerage which is attached to a firebox on the opposite side to that on which the digging apparatus is fitted. This steerage is pushed along by the reaction of the digging forks as they enter the soil, and, projecting as it does some 12 feet from the boiler, it enables the driver to guide the machine with ease and accuracy. When the digger has nearly reached the side of the field toward which it is traveling, one pair of wheels is brought to a standstill, while the other pair still revolve. This has the effect of causing the machine to wheel round like a company of well drilled soldiers, so that it is completely turned in its own length, and ready to make another journey across the field in the opposite direction over fresh soil.

The following is a description of the mechanism of the digger:

BOILER.

Type: Locomotive.			
Length of barrels	each	6 ft.	11½ in.
Diameter of barrels inside	"	2 "	4¾ "
Length of firebox, mean	"	3 "	3½ "
Width of " mean	"	2 "	1⅝ "
Height of " above grate	"	2 "	8 "
Area of grate	sq. ft.	6	0·25
Tubes, number (best lapwelded)			48
Tubes, diameter outside			2¼ in.
Tubes, length between plates		5 ft.	9 "
Heating surface firebox	sq. ft.	33	
" " tubes	"	180·6	
" " smoke boxes	"	3·6	
" " total	"	216·2	
Working pressure, lb. per sq. in.			80

The shell of the boiler is constructed throughout of Siemens steel plates, double riveted, tested by hydraulic pressure to 250 lb. per square inch. The firebox is of Lowmoor iron, stayed to the shell by 123 Lowmoor stays ⅝ diameter, 4½ inch pitch.

ENGINE.

Diameter of cylinder (steam jacketed)	9¼ in.
Length of stroke	12 "
Diameter of crank shaft	3⅜ "
Revolutions per minute	200

ROAD GEAR.

Diameter of road wheels	3 ft.	6 in.
Width of road wheels	1 "	11 "
Revolutions per minute		9·69

DIGGING GEAR.

Long spit		9¼ in.
Number of revolutions of forks per minute 34	Engine rev.	200
" " " " 42	" "	250
Short spit		6·4 in.
Number of revolutions of forks per minute, 48·8	engine rev.	200
Extreme width of forks		21 ft.

The shafts for the gear work and the main axles are of Bessemer steel. The whole of the gearing for driving the road wheels and the digging forks are of crucible cast steel, also the principal brackets for the gearing. The fork frames and cranks, the carriage frames and saddles, are constructed throughout of crucible steel castings.

The great value of steam digging consists in the exposure of a much greater superficies of soil to the action of the atmosphere than can be effected by any other mode of cultivation, and this is done without the least pressure on the soil after the operation. The sledging action of the plow is avoided, direct descent of the roots into the subsoil is obtained, and it is said that the crops grown on steam-dug land are almost universally better both in quantity and quality. When it is remembered that the arable land of Great Britain, if it were all steam-dug, would give employment to 16,000 of these implements, it will be seen that steam digging may possess an important future for agricultural engineers as well as for agriculturists.—*Iron*.

ADVICE TO YOUNG MECHANICAL ENGINEERS.

AT the close of the recent session of the Finsbury Technical College, Professor Perry, F.R.S., delivered an address to his second year students and some of their parents, to the following effect:

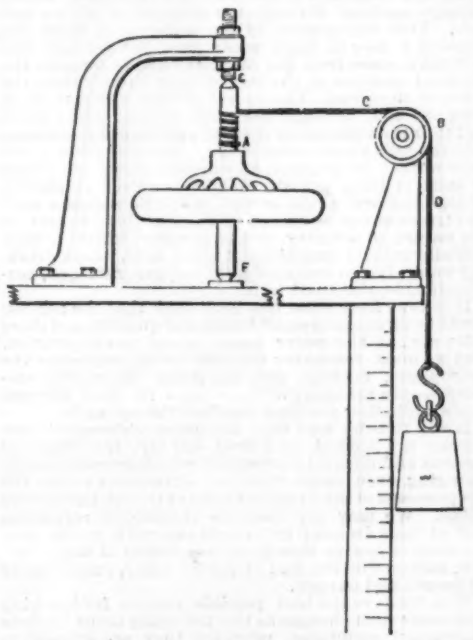
A question of peculiar importance to you mechanical engineering students is what you are to do when you leave college. The subject is a hackneyed one to me, for I have given advice to students in various previous years, but for you it is very different. You are going to have a perfectly novel experience, and the present is one of the most serious times of your lives. As I look at your faces, I think of the many who have left me since I began to teach about twenty years ago. I have heard that some of my old students are now cab drivers, some have occupied legislative and administrative positions in this and foreign countries. Some are in Japan or India, in charge of large engineering works. Some of my old Finsbury students, young as this college is, have already made their mark, others are already showing that they are "duffers." A good mechanical engineer must be a fairly good workman with his hands, but it is of even more importance that, whether or not he has manual skill, he shall at an early age have worked side by side in the shops with men as one of themselves, gaining slowly or quickly, as his sympathy and quickness may have determined, that peculiar kind of experience which is not to be obtained in any other way, and without which a manager of works is a mere Molesworth pocket-book bound in calf. How much more than a mere workman he can become depends partly on his having had a decently good liberal education, greatly upon his having had a good scientific education in mathematics, physics, and mechanics, and upon his power of drawing, but probably most of all upon his powers of imagination, his originality, his common sense, which lead to a cautious but respectful appreciation of new ideas. I admire very much the man who believes so much in the mathematical theories given in books that he is ready with a formula at every little difficulty in his practical work—I admire him, but I am not always able to imitate him. Indeed, you will find that one of your great troubles will be that you will dissociate your theory from your practical work. However much you may believe in theory, you will often forget all about it or refuse to apply it, except when you are writing or reading. This is often due to the fact that you are aware of the incompleteness of mathematical theories in general, and it will gradually come home to you that the good mechanical engineer must have a far more extended theory about mechanical things than is given in any book, or than he himself can formulate.

Now let us consider how you are equipped for entering the profession. About half of you can use the differential and integral calculus; you all have practical knowledge of what is meant by a differential coefficient; not one of you would, I am sorry to say, be able to satisfy an ordinary mathematical examiner, but I think that such knowledge as you have is handy; it is a tool kept for use rather than show. Remember, however, that it is not possible for you to become too good a mathematician. Your drawing is excellent. Even at the end of your first session you could all turn out drawings as different as possible from "drawing class" drawings. Not one worthy to be framed and admired by your fond female relations; but only a very experienced man could have told that your drawings had not come from a real drawing office. You cannot yet do any designing; that can only come after you have had the workman's experience. But if I asked one of you to go to Glasgow to sketch a machine, he would come back with every dimension right, not one missing, and he could turn out working drawings of that machine with all its details in such a style that the men in a shop would respect them and think them made by a regular well-paid draughtsman.

Of your work in practical geometry, chemistry, physics, and modern languages I need not speak. Let us consider your equipment in regard to mechanics; you have had lectures, numerical exercise work, and laboratory work on this subject. Among the numerous investigations which you have made in the laboratory it is difficult to choose one rather than another to illustrate my system. Let us take this well-used fly wheel. The M of a fly wheel, multiplied by the square of its number of revolutions per minute, gives the kinetic energy stored up in it in foot pounds. You are asked to measure experimentally the M of this fly wheel; the loop at the end of a cord goes over the pin A on the spindle, and is wrapped in turns round the spindle, then goes over the pulley, B, and has a weight, W, at its end. At time, O, the wheel is let go; in t_1 minutes—carefully observed—the cord drops off; in t_2 minutes from starting, the wheel has been brought to rest again by friction. The weight, W lb., multiplied by the height in feet through which it has fallen, gives the energy stored up in the wheel at time t_1, so that if the speed were then known, M could at once be calculated. But as we have no speed indicator, we take it that the motion is uniformly accelerated till the cord drops off, or we take $2\frac{n}{t_1}$ as the revolutions per minute at the time t_1. The corrections are of more interest. We have first to deduct the kinetic energy of W when the cord drops off. Then we must make experiments on the friction of the pulley, B, for the pull in the cord at C is less than what it is at D, and these experiments are themselves very interesting, for they are made with the two parts, C and D, vertical, so that the parallelogram of force principle must be brought in to make them available. Next we correct for the friction at the pivots, E and F. And here we observe that the average speed from t_1 to t_2 is the same as from O to t_1, and hence that from t_1 to t_2 the motion is uniformly retarded, and hence that there is as much energy wasted in any one revolution as in any other. If, then, we know the number of revolutions from t_1 to t_2, we know the energy wasted in one revolution, and we can correct for friction before the cord drops off; and so we make one correction after another, and there is hardly any limit to the amount of ingenuity required, as the corrections get less and less important. I remember that four gray-headed men worked together at this piece of apparatus once in the evening for five weeks, and when at length they had satisfied themselves with their corrections, they had practically used many times every important principle of mechanics, and they had acquired a handy working knowledge of all these principles.

You will perhaps allow me to refer to one other illustration of my system. Thirty of us have a field day with the engine which drives the large dynamo machine lighting the college. Each of you has on more than one occasion acted as stoker and engine driver, as oiler and tester of machinery of this college, lighting fires, taking indicator diagrams, weighing coals, opening and closing cocks, from seven in the morning till ten at night, so that the engine room is well known to all of you. We have three different steady loads during the trial. We divide into groups, and the half of each group ceases to take certain kinds of observation every ten minutes, and removes to another job. Each student takes the time at which he makes an observation. These observations are—taking indicator diagrams, checking the speed indicator, taking the temperature of the feed water, taking the quantity of feed water by the meter, whose accuracy you had tested already, taking the actual horse power passing through the dynamometer coupling on the shaft, whose accuracy some of you have measured; taking the boiler pressure, the pressure in the valve chest, the vacuum gauges at the vaporizing condenser on the roof and in the engine room, the quantity of coals used, the calorific power of the coals having already been measured by you, and making other mechanical measurements; measuring also the electrical horse power given out by the dynamo, the number of electric lights which are glowing, etc.

Each of you reduces his own observations in the way already described to you. He finds his indicated horse power, the feed water per hour per indicated horse power, the water per hour shown by his diagrams per indicated horse power, and so on; and when we have gathered all our observations into a great table, and each of you has seen with certainty how the total



INSTRUMENT FOR MEASURING THE ENERGY OF A FLY WHEEL.

energy of the coal is distributed—so much up the chimney, in the steam jacket, in condensation in the cylinder, to the condenser, in friction in the engine, etc., etc.—he has obtained a practical knowledge of the steam engine which no amount of reading or listening to lectures could possibly supply.

I need not apologize to you for showing you how you are equipped. I want to impress upon you the value of the training you have had. Like other men, you can make calculations from formulæ; but just think of the results of the experiments made by you on friction at different speeds, and notice the light which they throw upon the insufficiency of the formulæ which you must employ in making calculations. They not only do this, but they give you courage to make calculations, for you know now the extent of your ignorance and knowledge.

Some of you will, I think, become eminent in the mathematics of engineering. I am sorry to say that many of you will fail to pass our examinations, and will not obtain the college certificate. Now that you are about to leave us, I may tell you that this certificate business does not matter so very much after all. You have all done your best, I think, and I have nearly as much sympathy with those who fail in examinations as with those who pass. I have had a large experience of men, and know that the race is not always to the apparently swift. There is a crucial question to be asked you. Do you like mechanical engineering in any of its aspects? Do you love to fiddle with mechanical things? Have you been put into this line by your parents, or do you like it for itself? Would you prefer going into the church, or into a bank, or have you a hankering after law or doctoring? If so, now is the time to act upon that instinct; it is not too late; your education will not be wasted. However high you may have been in an examination list, give the thing up! If, however, you like mechanical engineering, stick to it, notwithstanding any failure to pass an examination. Far be it from me to disparage those who pass examinations well—you know that I honor them highly—but they will yet find out that some of their contemporaries whom they look upon as "duffers" will be magically successful as engineers if they love their profession, and bring to it the common sense in which few Englishmen are deficient.

Hitherto you have been learning how to learn your trade. You have been learning the principles underlying a trade, but not the trade itself. You have, it is true, acquired a considerable amount of skill. Some of you can chip and file and scrape as well as any fitter in the country. Some of you can set a bit of work in the shaping machine as skillfully as any man. But all this training has been given you that you may learn to be a good workman in three years instead of seven.

Under the apprenticeship system of the middle ages a man learning his trade lived with his master almost like a servant; it was a friendly kind of relationship, and the master taught him his whole trade; probably in the end he married his master's daughter and succeeded to the business. That system is now disappearing, except in some few parts of England; at Sheffield, for instance, it still survives in a very modified form. But, of course, when a master has many hundreds of hands at the present day, a boy is pitchforked into the works, and it is nobody's duty to teach him anything. I wish I had time to dwell on my own experience as an apprentice, rising gradually from three shillings a week in the first year, as duly noted on my indentures, by a shilling a week for seven years. Suffice it to say that I do not see why, with your training, you should not gain in two and a half or three years the skill and knowledge which the ordinary untrained boy, with much want of self-respect, and very often with harsh treatment from everybody, takes seven years to acquire.

It is usual now, when a young man does not enter works as an ordinary apprentice—who is very often in these days not indentured—for him to enter as an articled pupil, paying a premium. In civil engineering, and many other professions, I think that there is no great objection to this system; but in mechanical engineering, I think it a frightful mistake. No doubt, there are numerous exceptions to what I shall say. There are some young men who cannot be spoiled; but, as a rule, the articled pupil has the right to loaf around as he pleases. He is not earnest in his work; he expresses small regret when he breaks valuable tools or spoils his work. He has high and mighty notions of his importance; he cannot use his hands, but, in his own opinion, "he can outsuperintend any circus manager." He is afraid of dirty work; he is altogether out of sympathy with the workmen from whom alone he can learn his trade, and in most cases he has to try to learn some other profession at the end of his apprenticeship.

And now, at last, I have come to the advice which I have to give you. You must enter a general engineering shop at once. You must find such a shop where you will be taken without premium for two or two and a half years. You will find that masters have a prejudice against young men coming from a college. We are gradually living this prejudice down. But there it is, and it must be taken into account. I have had it myself when I have been a manager or an employer, for the young man from the college is often a frightful nuisance in a shop. You must not only pay no premium, but you must get some wages, however small, from the beginning; for if you are in receipt of wages you will at all events try to be worth your pay, and you will have a very valuable feeling of responsibility. Those of you who have most money to spare will derive most benefit in following this advice. The father of an old pupil came to me once, and almost with tears in his eyes begged me to let his son enter works, paying a premium, as the son would not do it without my consent, and I refused.

Here, then, on your leaving the college you have something to do which will test your fitness to become engineers. Talk with any experienced man on the subject, and he will tell you that it is impossible for you to obtain the sort of work I speak of; and now I say that an engineer is a man who often attempts to do what other people say is impossible. You must interview masters and managers and foremen—you must not feel so disheartened after twenty failures but that you can go to the twenty-first shop as gayly as to the first. I say to you that it is quite possible for you to obtain just such work as I have described, and it is of the utmost importance to you that you should obtain it. Some old Finsbury students have tried shops all the way from London to Leith before succeeding. Here are letters from nearly all my old Finsbury students; most of them describe their difficulties and their great appreciation of a good job when they obtained it. Here is a letter from one of our best students of last year: he stayed two months at home in the country, writing innumerable letters. I convinced him that he could never succeed in this way, and then he went off on his personal search for work, and after several disappointing days at last obtained just such a job as I have described. Any one of you who fails to succeed in this quest may rest satisfied that he has too little fortitude, courage, and patience to become a successful engineer. And you need not think that in this persistent and modest search for the only kind of work which can complete your education you are wanting in manliness. We do not think a member of Parliament wanting in manliness when he canvasses a constituency. Almost every old Finsbury student has succeeded in this quest which so many people have told them is an absurd one. [Here Professor Perry read extracts from numerous letters from old students, describing their work. Some of them are preparing for Whitworth scholarships or engineering degrees in the Royal University of Ireland. All of them were enthusiastic as to the result of their following the above instructions.] It is not good to get work too easily, as you will not appreciate correctly such a job as I have spoken of unless it is the result of a number of personal applications.

And now as to your behavior in the shops. Remember that your aim is to learn all that workmen can teach you. There must be no shirking of hard work, or rough work, or dirty work, no fear of working overtime should it be necessary; you must welcome a sudden call for unusual exertion as a new and valuable experience. Remember, too, that you must learn from the men; who else is there to teach you the trade? Now some of these men are ignorant of theory, many of them are prejudiced in curious ways, but don't fall into the common mistake that because a workman has not read much, and knows but little of thermodynamics, that therefore he is an ignorant man. I knew a man who could barely read or write who was one of the cleverest engineers I ever knew. No one so valuable as he in a breakdown of an engine. He could take indicator cards and set almost any kind of valve motion with an instinctive perception of what it was just right to do, which always excited my admiration. If you treat workmen sympathetically, you will

find that, as a rule, they are very good men, good citizens, trying their best to make the world better, and helping each other to quite an extraordinary extent. But if you go among them as if you were china and they were crockery, if you put on "side" and swagger about your poor, pitiful theoretical knowledge, if you let them see that you come of better blood, if you scorn them because your families are well to do in the world, if, in fact, you do not let it be seen in all your actions that you regard them as men and superiors—for be sure they are your superiors until you acquire their skill and knowledge—then you may bid good-by to all idea of help from them, and you may bid good-by to the idea that you will ever be able to lead men, either as a foreman or manager of works. If you want to see all their evil qualities, treat them as inferiors; if you want to see all their good qualities, treat them sympathetically as if they were really of your own flesh and blood. Of course there are black sheep among them, as there are some black sheep among yourselves, but remember that not one of them is as black as you will think him to be. The advice I am giving you I never needed myself. I never yet came in contact with a decently skillful workman without feeling his superiority to myself; and I seldom meet any man who does not impress me in some direction with his superiority to myself, and I have never regretted letting such a man know, in some unobtrusive way, what I thought of him.

As for study, keep up your reading if possible. It is so very difficult to read after a hard day's work—I used often to go to sleep over my books—that I regard men who go to evening classes as quite exceptional men. But keep up your reading as much as possible. As to the cultivation of your imaginations, I am sorry to think that young men of twenty years ago were in a better position than you. They had read novels and poetry, they danced, and were fond of music. It is rather useless to give advice to you on this head.

There is one very important matter on which I wish to touch, and then I shall have done. Some of you intend, I think, to try for scholarships at certain more advanced engineering colleges, so as to proceed with your college studies for another three years. Now I want you to understand that I appreciate at their proper high value the temptations offered you—to obtain scholarships, to get an advanced, thorough, mathematical training, to work in Professor ——'s laboratory, and listen to his teaching. To men like you and me these are very great temptations; but let me tell you that these temptations ought not to be yielded to. Your ages are now on an average seventeen years. If you enter the shops now, you can become good workmen; but if you enter shops at the end of another three years—and without entering shops, how is it possible to become mechanical engineers?—you will not be able to learn. It will be too late to make boys of yourselves at the ages of twenty, or twenty-one, or twenty-two years. Having had a most perfect theoretical training, to put yourselves meekly and modestly under the orders of a workman; to accept his statements without a little sneering or verbal protest; at an age when you will be thinking of love making and dressing like a "masher;" to roughen your hands in doing coarse, dirty work; the thing is impossible. Why even I, at the age of fifteen, with nobody to advise me, found that I could not become a good workman for this sort of reason, because I had a pitiful little knowledge of mathematics, and chemistry, and physics, and held myself above my work, and greatly have I regretted it since. No; I advise you to go at once to works, and at the end of two or three years get one good session's teaching from Professor ——. Think of going to his magnificent laboratory with your present equipment, and in addition a real knowledge of actual work. You will learn more in one session after your training in the works than you can learn now in three, and you will have learned besides to be a thoroughly good workman, at the only time of your life when such a thing is possible.

[NATURE.]

TIMBER, AND SOME OF ITS DISEASES.*

By H. MARSHALL WARD.

VIII.

IF the leaves are stripped from a timber tree early in the summer, or during their young conditions in the spring, the layer of wood produced in the current year—and probably even that formed next year—will be poor and thin. This is simply a fact of observation, and does not depend on what agent deprives the tree of its leaves. Those oaks which suffered so greatly from the ravages of certain tiny caterpillars this last summer (1887)—many of them having all their leaves eaten away before July—will have recorded the disaster by a thin annual ring of wood. It is true the more vigorous trees produced (at the expense of what stores of food materials remained over) a second crop of leaves in August, and so no doubt the zone of wood will prove to be a thin double one, but it is at the expense of next year's buds.

Now there are very many foes which injure the leaves of our timber trees, and I wish to show, as clearly as possible in a short article, how it comes about that injury to the leaves means injury to the timber. The sum total of the matter is that the substances which are to be sent down to the cambium, and converted through its agency into wood, are produced in the cells of the leaves; consequently, from our point of view, when an insect or a fungus consumes the substance of the leaves, it consumes timber in prospective. Similarly, when the leaves are removed from a tree by any agent whatever, the latter is robbed in advance of timber. A leaf, generally speaking, is an extended, flattened portion of a branch, covered by a continuation of the epidermis of the branch and containing a continuation of its other tissues—the vascular bundles of the branch being continued as the venation, and the cellular cortex reappearing as the green, soft tissue of the leaf. The epidermis of the leaf is so pierced at hundreds or thousands of nearly equidistant points, that gases can enter into or escape from all its tissues; at these points are the so-called *stomata*, each stoma being a little apparatus which can open and close according to circumstances.

These openings lead into excavations or passages between the loose cells of the softer leaf tissue, and if we supposed a very minute creeping organism to enter one of the stomata, it would find itself in a labyrinth of intercellular passages. Supposing it able to traverse these, it could pass from any part of the leaf to any other between the cells; or it could emerge again from the leaf at thousands of places—other stomata. In traversing the whole of the labyrinth, however, it would pass over many millions of times its own length. Moreover, it would find these intercellular passages filled with a varying atmosphere of diffusing gases—oxygen, nitrogen, the vapor of water, and carbon-dioxide being the chief. It would also find the cell walls which bound the passages damp, with water continuous with the water in the cells. If we suppose our hypothetical traveler threading the mazes of these passages at night, and able to perceive the changes which go on, it would find relatively little oxygen and relatively much carbon-dioxide in the damp atmosphere in the passages; whereas in the daylight, if the sun was shining brightly on the leaves, it would find the atmosphere rarer, and relatively little carbon-dioxide present, but an abundance of oxygen. These gases and vapor would be slowly moving in and out at the stomata by diffusion, the evaporation of the watery vapor especially being quicker on a dry, hot, sunny day.

Inside the cells between which these tortuous passages run are contained structures which have much to do with these changes. Each of the cells I am considering contains a lining of protoplasm, in which a nucleus, and a number of small protoplasmic granules, colored green, and called chlorophyl corpuscles, are embedded. All these are bathed in a watery cell sap.

Now, putting together in a general manner some of the chief facts which we know about this apparatus, it may be said that the liquid sap inside the cells gives off water to replace that which escapes through the damp cell walls, and evaporates into the above named passages and out through the stomata, or at the surface. This evaporation of the water is in itself the cause of a flow of more water from behind, and this flow takes place from the vascular bundles forming the so-called venation of the leaf, coming directly from the wood of the stem. The course of this water, then, is from the soil, through the roots, up the young wood and into the venation of the leaf, and thence it is drawn into the cells we are considering. But this water is not pure water. It contains in solution small quantities of salts of lime, potash, magnesia, nitric, sulphuric, and phosphoric acids, as well as a little common salt, and traces of one or two other things. It is, in fact, of the nature of ordinary drinking water, which always contains minute quantities of such salts. Like drinking water, it also contains gases (oxygen, nitrogen, carbon-dioxide) dissolved in it.

It follows from what has been said that the cell sap tends to accumulate small increasing quantities of these salts, etc., as the water passes away by evaporation. But we must remember that the living contents—the protoplasm, nucleus, and the green chlorophyl corpuscles—use up many of these salts for their life purposes, and other portions pass into the cell walls.

It will thus be seen that the green chlorophyl corpuscles are bathed by a fluid cell sap, the dissolved gaseous and mineral contents of which are continually changing, even apart from the alterations which the life processes of the living contents of the cell themselves entail. We may say that the chlorophyl corpuscles find at their disposal in the cell sap, with which they are more or less in direct contact, traces of salts, oxygen, carbon-dioxide, and of course water, consisting of hydrogen and oxygen.

Now we have the best possible reasons for knowing that some such changes as the following occur in these chlorophyl corpuscles, provided they are exposed to sunlight. They take up carbon-dioxide and water, and traces of minerals, and by means of a molecular mechanism which is as yet unexplained in detail, they perform the astonishing feat—for it represents an astonishing transformation when regarded chemically and physically—of tearing asunder, by the aid of the light, the carbon, hydrogen, and oxygen of the carbon-dioxide and water, and rearranging these elements in part so as to form a much more complex body—starch, or an allied compound, oxygen being at the same time set free.

It is, of course, not part of my present task to trace these physiological processes in detail, or to bring forward the experimental evidence on which our knowledge of them is based. It must suffice to state that these compounds, starch and allied substances, do not remain in the chlorophyl corpuscles, but become dissolved and carried away through certain channels in the vascular bundles of the venation, and thence pass to wherever they are to be employed as food. The chemical form in which these substances pass from one cell to another in solution is chiefly that of grape sugar, and it is a comparatively easy observation to make that the cells so often referred to contain such sugar in their sap.

We are only concerned at present with the fate of a portion—but a very large portion—of this starch and sugar. We can trace them down the vascular bundles of the venation, through the leaf stalk, into the cortex, and eventually to the cambium cells, and it is necessary to be quite clear on the following points: (1) The cambium cells, like all other living cells which contain no chlorophyl, need to be supplied with such foods as sugar, starch, etc., or they starve and perish; (2) since these foods are prepared, as we have seen, in the leaves, and in the leaves only, it is obvious that the vigor and well-being of the cambium depend on the functional activity of the leaves.

We have already seen how the cambium cells give rise to the young wood, and thus it will be clear how the formation of timber is dependent on the functional activity of the leaves. Moreover, it ought to be mentioned, by the way at least, that it is not only the cambium which depends upon the leaves for its supplies—all the roots, young buds, flowers, and fruits, etc., as well as the cortex and cork-forming tissues, are competitors for the food supply. Now it is clear that if we starve the buds, there will be fewer leaves developed in the following year, and so next year's cambium will again suffer, and so on.

I have by no means traced all the details of even the first ramifications of the complex network of correlations implied by this competition of the various organs and tissues for the food supplies from the leaves; but probably the following proposition will be generally clear: If the leaves are stripped, the cambium suffers starvation to a greater or less extent, depending on the intensity of its competition with other tissues, etc. Of course a starved cambium will form less wood, and, it may be added, the timber will be poorer.

Again, even if the leaves are not stripped quickly from the tree, but the effect of some external agent is to shorten their period of activity; or to occupy space, on or in them, and so diminish the amount of leaf surface exposed to the light and air; or to block up their stomata, the points of egress and ingress for gases and water; or to steal the contents of the cells—contents which should normally be passed on for the growth, etc., of other parts of the tree—in all or any of these ways injury to the timber may accrue from the action of the agent in question. Now there are numbers of parasitic fungi which do all these things, and when they obtain a hold on pure plantations or forests, they may do immense injury before their presence is detected by any one not familiar with their appearance and life histories.

The great difficulty to the practical forester who attempts to deal with these "leaf diseases" is at least twofold; for not only are the leaves so numerous and so out of reach that he can scarcely entertain the idea of doing anything directly to them, but (and this is by no means so clearly apprehended as it should be) they stay on the tree but a short time as a rule, and when they fall are a continual source of re-infection, because the spores of the fungi are developed on them. It is a curious fact that those fungi which are known to affect the leaves of forest trees nearly all belong to two highly developed groups—the Uredineæ and the Ascomycetes—and the remarkable biological adaptations which these parasites exhibit for attacking or entering the leaves, passing through periods of danger, and so on, are almost as various as they are numerous. Some of them, such as the *Erysipheæ* or mildews on beeches, oaks, birches, ashes, etc., only form small external patches on the leaves, and do little if any harm where the leaf crown is large and active. Others, such as many of the very numerous *Sphæriaceæ* and their allies, which form small dark-colored flecks and spots on leaves, may also be looked upon as taking only a slight tax from the leaves. Even in these cases, however, when the diseases become epidemic in certain wet seasons, considerable damage may accrue, because two chief causes (and many minor ones) are co-operating to favor the fungus in the struggle for existence. In the first place, a continuously wet summer means loss of sunlight and diminished transpiration, etc., to the leaves, and so they form smaller quantities of food materials; and secondly, the damp in the atmosphere and leaves favors the fungi, and so they destroy and occupy larger areas of leaf surface.

It should be mentioned here, by the way, that all leaves of all trees are apt to have fungi on them in a wet summer, but many of these are only spreading their mycelia in all directions over the epidermis, in preparation, as it were, for the fall of the leaf; they are saprophytes which feed on the dead fallen leaves, but cannot enter into them while yet alive. In some cases, however, this preparation for the fall is strikingly suggestive of adaptation toward becoming parasites. I will quote one instance only in illustration of this: On the leaves of certain trees in Ceylon, there was always to be found in the rainy season the much-branched mycelium of a minute *Sphæria*. This formed enormous numbers of branches, which on the older leaves were found to stop short over the stomata, and to form eventually a four-celled spore-like body just blocking up each stoma on which it rested. So long as the leaf remained living on the tree, nothing further occurred; but wherever a part of the leaf died, or when the leaf fell moribund on the ground, these spore-like bodies at once began to send hyphæ into the dying tissue, and thus obtained an early place in the struggle for existence among the saprophytes which finished the destruction of the cells and tissues of the leaf.

There is another group of fungi, the *Capnodiæ*, which form sooty black patches on the leaves, and which are very apt to increase to a dangerous extent on leaves in damp, shady situations. These have no connection with the well known black patches of *Rhytisma* from which the leaves of our maples are rarely free. This last fungus is a true parasite, its mycelium penetrates into the leaf tissues, and forms large black patches, in and near which the cells of the leaf either live for the benefit of the fungus alone, or entirely succumb to its ravages. After the leaf has fallen, the fungus forms its spores. Nevertheless, although we have gone a step further in destructivenes, foresters deny that much harm is done to the trees—no doubt because the foliage of the maples is so very abundant. Willows, pines, and firs suffer from allied forms of fungi.

But it is among the group of the *Uredineæ* or rusts that we find the most extraordinary cases of parasitism, and since some of these exhibit the most highly developed and complex adaptations known to us, I propose to select one of them as the type of these so-called "leaf diseases." This form is *Coleosporium Senecionis* (*Peridermium Pini*), rendered classical by the researches of several excellent botanists.

It is true, *Coleosporium Senecionis* is not in some respects the most dangerous of these fungi—or, rather, it has not hitherto been found to be so—but in view of the acknowledged fact that foresters have not as yet been able to devise practical measures against the ravages of these numerous rust fungi, and since we are as yet very ignorant of the details of the biology of most of them, it seems advisable to choose for illustration a form which shows in a distinct manner the complexities of the subject, so that those interested may see in what directions biologists may look for new results. That the story of this fungus is both complicated and of great biological interest will be sufficiently evident from the mere recital of what we know concerning it.

(To be continued.)

* Continued from SUPPLEMENT, No. 656, page 10474.

TO MEND BROKEN MARBLE.—Take plaster of Paris, soak in a saturated solution of alum, then bake in an oven, after which grind to powder. It is then used as wanted, being mixed with water and applied. It sets into a very hard composition, capable of taking a very high polish, and may be mixed with various coloring minerals to produce a cement of any color capable of imitating marble.

THE ELDER STATUE.

OUR illustration shows the statue lately erected at Govan, by public subscription, to the memory of John Elder, engineer and ship builder.

John Elder was born in Glasgow on March 8, 1824, and received his elementary education in the high school of that city. In those arts associated with mechanical science he was an apt pupil, and made rapid progress in acquiring the fundamental principles which he, in after years, so successfully carried into practice. The only university education he received was in the civil engineering classes in the Glasgow College. The workshop was, indeed, his great school, and his father was his most painstaking and valuable teacher. He served his apprenticeship of five years as an engineer with Robert Napier, under the direct control of his father, David Elder, and after a brief sojourn in one or two works in England, he returned to Napier's works to take charge of the drawing office. Here he gained great experience. In 1852 he joined the firm of Randolph, Elliott & Co., who were then millwrights, but on the accession of young Elder became marine engineers, the title of the firm being at the same time changed to Randolph, Elder & Co. Shipbuilding was added in 1860, and eight years afterward John Elder became sole proprietor, but subsequently the title was changed to John Elder & Co. The subject of this notice was seldom content with machines and tools as he found them, and was continually improving. His great idea was to add to the efficiency of the marine engine by reducing the friction of the parts, increasing the power, and at the same time decreasing the consumption of fuel. Among his first acts was to experiment on Watt's old steam jacket, greatly improving it, and he thereby brought it again into favor. The crowning act of his genius, however, was the application to the marine engine of the principle of expanding steam in two cylinders, now called the high and low pressure cylinders. The new engine was described by himself in the patent taken out by Charles Randolph and himself on January 24, 1853, as "an arrangement of compound engines adapted to the driving of the screw propeller. The engines are vertical, direct acting, and geared. The pistons of the high and low pressure cylinders move in contrary directions and drive diametrically opposite cranks with a view to the diminution of strain and friction." These engines were placed in the SS. Brandon, built in 1854. In July the vessel went on her trial, which was closely watched by all engineers. The consumption of fuel was reduced from about 4¼ lb. per indicated horse power to 3¼ lb. Encouraged by the success of this, the first venture, Mr. Elder continued his experiments and made several improvements on the engine. The Admiralty, in 1863, adopted, in the Constance, the compound engine as improved, and to test the invention in a thorough way, this vessel, with two of similar dimensions, Octavia and Arethusa, having other kinds of engines, went on a trip from Plymouth to Funchal, in Madeira. When the Constance was within 30 miles of Funchal, she was 130 knots ahead of the Octavia and 200 knots from the Arethusa. The engines of the latter two had then to be stopped, owing to the coal on board being nearly exhausted, and they finished the distance under canvas. The superiority in power of the Constance's engines was established, and her consumption of coal per indicated horse power was less, being 2·31 lb., while it was 3·17 lb. in the Octavia and 3·64 lb. in the Arethusa. The mean indicated horse power of the engines in the three vessels during the trip was 1747, 1399·8, and 1052·2 respectively. In other respects, too, the Constance gained the advantage, and so thoroughly was the value of the compound engine established that it was almost universally adopted thereafter. Mr. Elder and his partner continued to improve the engine, over a dozen patents being taken out by them for various apparatus, but it is too late in the day to write more on the subject.

The Elder statue, as is most fitting, is erected within the bounds of the beautiful park of 37 acres given by Mrs. John Elder to the people of Govan, at a cost of upward of 50,000*l*. It is situated in the west end of Govan, opposite the Fairfield works, which by the genius and perseverance of John Elder attained such an eminent position among shipbuilding and engineering establishments. The park, as is testified by an inscription on the band stand, was laid out by his widow as a memorial of her husband, John Elder, and his father, David Elder, both of whom had always taken a deep interest in the working classes. While such a gift was well fitted to remind passing generations of the man, the people of Govan had decided to do something as much to show their respect for and gratitude to the man as to commemorate his name his genius, and his good deeds. The beautiful erection which we illustrate is the result of this decision.

Mr. J. E. Boehm, R.A., the artist, must be congratulated on the excellence of the production, not only from an artistic point of view, but in consideration of the good likeness. In effecting the latter, he was assisted principally by a bust of the late Mr. Elder, executed by Mr. Power, of Florence, and by photographs. The statue, which is 10 ft. in height, represents John Elder standing in an attitude which those who knew him best will at once recognize as a favorite one. It is easy and very graceful. The countenance clearly indicates the reflective habits of the man, while the contented, almost sweet, smile in the eyes betokens a measure of success. This one might reasonably trace from his glance to the compound engine, a model of which stands on his left side, and which his hand touches approvingly. The pose of the head, which slightly inclines forward to enable the eyes to rest on the engine, must have been a difficult one to model; but it has been successfully done, and the statue, as we have already hinted, is a true example of Mr. Boehm's art. It was cast in bronze at the works of Mr. Moore, of Thames Ditton, Surrey.

The masonry on which the statue and engine stand is 12 ft. in height, and the base is 9 ft. square. The pedestal proper is composed of three massive blocks of red Peterhead granite highly polished, elevated on two steps of finely axed gray Aberdeen granite. The red granite blocks, which make up the larger and more important part of the structure, are magnificent stones of "brilliant color." It is difficult to find such large masses of this mineral without large spots of dark color, which very much detract from its beauty, but the sculptors in this case have been fortunate in getting stones remarkably free from this disfigurement. The designer has been equally happy in the adornment. The mouldings of the upper base and the cornice of the pedestal, the only carvings on the structure, are similar to those usually found on pedestals of Corinthian columns, but boldly treated to suit the material. The ogee moulding on both base and cornice is covered by bronze acanthus leaf ornament, supplied by the sculptor. The effect is to very much enhance the appearance of the dado, which on all four sides is about 5 ft. high by 4 ft. broad. On each side there is a recess into which has been fitted a bronze panel, and each of these tablets bears a different inscription as appended. The order in which the paragraphs are given indicate the inscriptions on the front, right, left, and back panels.

"John Elder, engineer and shipbuilder, born at Glasgow, March 8, 1824, died September 17, 1869."

"To commemorate the achievements of his genius, and in grateful acknowledgment of his services to the community among whom he lived, this statue was erected by public subscription, July, 1888."

"By his many inventions, particularly in connection with the compound engine, he effected a revolution in engineering, second only to that accomplished by James Watt, and in great measure originated the developments in steam propulsion which have created modern commerce."

"His unwearied efforts to promote the welfare of the working classes, his integrity of character, firmness of purpose, and kindness of heart, claim, equally with his genius, enduring remembrance."

THE JOHN ELDER MEMORIAL.

The pedestal is surrounded by a number of pillars made of Aberdeen gray granite, connected by wrought iron chains. The sculptor work was done by Messrs. Alex. MacDonald & Co., limited, at their celebrated Aberdeen granite works. The red and gray granite blocks, of course, are from their own quarries, and were worked at Aberdeen. The statue was also raised into position by them at the request of Mr. Boehm.

An interesting ceremony took place during erection of the masonry. Ex-Provost Campbell, Govan, who, as chairman of the executive committee, has taken an energetic part in carrying out the proposal, placed in a cavity in the center of one of the stones forming the pedestal a casket containing several documents connected with John Elder and his family, including a portrait in enamel of the deceased gentleman, a photograph of his wife, an engraved portrait of his father, a printed memoir of John Elder, a patent specification of improvements by John Elder on steam engines and boilers, marked "A.D. 1862, 25th April, No. 1214," and several documents in connection with the Govan Park and burgh. The casket was hermetically sealed, and on the cavity itself was placed a granite cover similarly sealed.—*Engineering.*

ELECTROLYSIS BY ALTERNATE CURRENTS.

A VERY interesting paper has been communicated to the Academie des Sciences by MM. G. Maneuvrier and J. Chappuis with reference to the evolution of gas by means of alternate currents. When alternate currents are sent through an ordinary voltameter, with plates or large platinum wire electrodes immersed in water acidulated with pure sulphuric acid, no evolution of gas occurs, and it appears as if the acidulated water were not decomposed at all by alternate currents. For instance, with current of four or five amperes at 250 to 300 volts, which would easily light either arc or incandescent lamps, no traces of evolution of gas at the electrodes can be observed, provided the dimensions of the electrodes exceed one millimeter ($\frac{1}{25}$ in.) diameter, and four or five centimeters (1½ in. or 2 in.) in length. The opinion has thus been promulgated that alternate currents do not produce electrolytic action. But the authors observe that this opinion is erroneous, and the absence of electrolytic action is only apparent. If very fine wires are substituted for large electrodes in the voltameter, the same alternate currents immediately cause an abundant discharge of gas. The authors consider that a double chemical action goes on where large electrodes are used, and indicate that, with proper precautions, the reactions, direct and indirect, are strictly proportionate to the quantity of electricity traversing the voltameter. The total effect may be realized by utilizing the double chemical effect by forming suboxides, and in this manner it would be possible to construct an electric meter for use on alternate current systems. They remark, however, that the evolution of explosive gases in this way renders the experiments exposed to continual small spontaneous explosions if certain precautions, which they intend to indicate in a further communication, are not taken.

ON THE PROPER SIZE OF TELEPHONE CONDUCTORS.

By DAVID BROOKS.

THE long distance telephone company work metallic circuits of No. 16 American gauge between Philadelphia and New York, the length of conductors being slightly over 200 miles, the distance by line being 100 miles, four miles of which are under ground or water, making eight miles of conductors under ground and water. The telephones work well; far better, indeed, than the local service in the city for even as short a distance as one quarter of a mile, even if they use the same gauge conductor. With the metallic circuit the resistance is fully eight hundred times that of these short lines. I mention this to show that conductivity or low resistance has very little to do with good telephonic service. In the one instance we get rid of inductive disturbances, and in the other we do not. Take an ordinary circuit, say one mile in length. Say that each receiver has a resistance of 100 ohms, and the induction coil 300 ohms, making a total of 400 ohms for the resistance of one instrument. Calling the conductor 20 ohms, we have a total resistance of 820 ohms in the circuit. Now, substituting a No. 21 gauge conductor, which has a resistance of about 70 ohms per mile, we have increased the resistance of the circuit about six per cent., and theoretically increased the magnetic effect six per cent. Now the No. 16 gauge wire has twice the surface of the No. 21 gauge, and gathers twice the quantity of inductive disturbance. It has twice the electro-static capacity and twice the retardation if electro-static capacity and retardation are identical.

There is no trouble hearing the voice in these short circuits in either case, but the difficulty lies in getting distinct articulation. As an illustration, we have a telegraph cable of 53 conductors on the Pennsylvania Railway between Broad and Thirty-second streets, a distance of 1½ miles. Twenty-eight of the conductors are in use, mostly for telegraphic purposes. The other 25 are idle. Using one of the wires with the telephone, it works fairly well, but if we bunch all the idle wires at each end and use them as a single conductor, we reduce the resistance of the conductor twenty-fivefold, and we increase the inductive disturbances to that extent, and develop a noise resembling that of a million promiscuously-tuned Chinese gongs. We can get no speech over that bunched conductor.

There is another view which may be taken of the case and the effects ascribed to self-induction, or as our European electricians now express it, "electro-static inertia." In reference to that phenomenon I will quote from Dr. Oliver J. Lodge. He states: "There is a remarkable fact concerning electrical currents of varying strength, which has been lately brought into prominence by the experimental skill of Prof. Hughes, viz., that a current does not start or stop equally and simultaneously at all points in the section of a conductor, but starts at the outside first. The fact is naturally more noticeable with thick wires than with thin, and it is especially marked in iron wires. . . . To illustrate this matter further, rotate a common tumbler of liquid steadily for some time and watch the liquid, dusting powder, perhaps, over it to make it more visible, you will see first the outer layer begin to participate in the motion and then the next, and then the next, and so on, until at length the whole is in rotation. Stop the tumbler and the liquid also begins gradually to stop by a converse process." Again he states: "We learn from all this that whereas, in the case of steady currents, the sectional area and material of the conductor are all that need be attended to, the case is different when one has to deal with rapidly alternating currents, such as occur in a telephone."

I am not familiar by practice or experiment with electro-static inertia, but infer from what I read that it is unfavorable for the use of large sized conductors for telephone purposes. I am firm in the belief, however, that small conductors, when used for ordinary lengths, are far preferable to those that have been heretofore employed. That for overhead wires strung on poles or house tops, a phosphor-bronze conductor, on account of its strength and small diameter, is far superior to iron or copper, because it can be made with very small diameter, and yet have sufficient strength and conductivity. I believe also that there have been thousands or hundreds of thousands of dollars spent for copper which could have been saved and a better service obtained by using smaller sized conductors.

Before the conductors referred to in the iron pipe were connected to the overhead conductors, a number of experiments were made with telephones, using the iron pipe for the return circuit, so as to compare its effect with that of the complete copper metallic circuit. No inductive disturbance was perceived in either case, nor did the copper metallic circuit show any advantage over the circuits using the pipe for the return current. In the center of the cable is a smaller sized wire, No. 18 American gauge, upon which we still use telephones; and, although there are heavy dynamo currents upon four of the No. 16 conductors in the same cable, or

group, the No. 18 conductor for telephone purposes, using the pipe for the return circuit, works much clearer and better than any of the circuits of the local telephone company, whose wires are strung upon poles or house tops.

And this brings to my mind a suggestion of Oliver Heaviside, that electro-static inertia, or self-induction, might be neutralized by mutual induction, since it does appear that the iron pipe has something to do with the good working of the telephone conductor.—*The Electrical World.*

THE MECHANISM OF ELECTROLYSIS BY ALTERNATING CURRENTS.

IT is considered as an established fact, say MM. J. Chappuis and G. Maneuvrier in *Comptes Rendus*, that we cannot decompose sulphate of copper by alternating currents. The absence of all electrolytic phenomena in this case is explained by supposing that the copper deposited on each electrode is immediately redissolved by the inverse current. This negative experiment is even presented as a proof of the equality of the two successive induced currents as far as their quantity of electricity is concerned. We have been enabled to justify this explanation by rendering the decomposition of sulphate of copper visible, just as we have done with acidulated water, though this novel experiment is both more complex than the former (*Comptes Rendus*, June 18, 1888) and more difficult to carry out.

If we substitute in the platinum wire voltameter a strong solution of sulphate of copper for the acidulated water, currents of a mean intensity of 2½ amperes, which previously produced a plentiful escape of detonating gas, produce nothing in the sulphate except a considerable heating, but if we then reduce the dimensions of the electrodes to 0·1 millimeter in diameter and 20 millimeters in length (= about 6 square millimeters of surface), there appears at once an escape of gas and a deposit of copper.

The electrolysis succeeds equally well with copper electrodes of the same dimensions. As soon as the current passes, we see arise a sheet of fine bubbles and a reddish brown cloud of pulverulent copper, and the electrodes themselves quickly take the aspect of spongy copper freshly reduced.

It seems, therefore, to follow from the whole of our experiments that, in electrolysis by alternating currents, it is always possible to reach a sort of equilibrium between the rate of decomposition of the electrolyte and the rate of recombination of its elements.

When once this equilibrium is reached, there is no longer, or, at least, there no longer appears, an electrolysis properly so called. But then all the circumstances which may make the former rate to predominate over the latter will cause the products of the electrolysis to reappear; and, on the contrary, all which tend to make the rate of decomposition predominate will make such products again disappear.

In the first rank of the conditions which accelerate the electrolysis, we must name the *density* of the current, that is, the ratio of its mean intensity to the surface of the electrodes. It is evident that if, on the one hand, we increase the quantity of electricity which traverses the electrode, and, on the other hand, diminish the surface of the electrodes, we shall cause the rate of decomposition to predominate over the rate of recombination and promote the appearance and the liberation of the products of electrolysis, as our experiments have verified in the electrolysis of acidulated water.

We conceive equally that the electrodes and the electrolyte may affect the rate of recombination by their chemical affinities or their physical properties. The facility of electrolysis must, therefore, depend also on the nature of the electrodes and the electrolyte. This is what our comparative experiments have verified in the electrolyses of acidulated water and of sulphate of copper, both by platinum and copper electrodes.

We may further foresee that the greater or less rapidity of the alternations, all other things being equal, must play an important part in the appearance or disappearance of the electrolytic phenomena. For if we suppose that the succession of the two induced currents becomes so slow that the electrolytic products of the first current have disappeared from the electrode, whether by direct disengagement or by diffusion, before the products of the inverse current have appeared there, no more recombination will be possible: each of the alternating currents will behave successively in the voltameter like a continuous current of brief duration. We see, then, that, all other conditions being equal, a retardation of the alternations must facilitate the appearance of electrolysis, while the acceleration of the alternations produces the contrary effect. This we have been able to verify by direct experiments.

The use of dynamos with a separate exciter has enabled us to vary the rapidity of the alternations without affecting the mean intensity, nor, consequently, the density of the currents. On the one hand, by raising the speed of the machine from 1,500 to 2,600 turns per minute, we could raise the number of inversions from 100 to 173 per second. On the other hand, by suitably modifying the intensity of the inducing magnetic field, by means of the exciting current, we could keep the mean intensity of the induced currents constant. Under these conditions we have made the two following experiments:

1. The machine turning at its ordinary speed (2,000 turns per minute, corresponding to 133 alternations per second). We regulate the intensity of the currents so as to maintain the state of equilibrium, that is, to cause all liberation of gas in a voltameter with acidulated water to disappear. If at this moment we let the velocity sink to 1,500 turns, we see the gas reappear and freely liberated at the electrodes.

2. When the machine is turning at its ordinary rate of 2,000 turns, we regulate the density of the current so as to give a distinct and regular escape of gas. If at that moment we raise the speed to 2,600 turns, all the escape at once disappears.

In either case we can annul the effect of this variation of speed by a suitable modification of the density. Thus in the first experiment we can cause the gas to disappear again by enlarging the surface of the electrodes, and in the second experiment they can be made to reappear by reducing this surface.

We see, then, that the rapidity of the alternations and the variations in the density of the currents affect the electrolysis in opposite directions, and that it may be manifested with currents of low density if the alternations are sufficiently slackened. This explains how, in 1837, De la Rive could easily decompose acidulated water by the alternating currents of the magneto-electric machines then recently invented. He succeeded in realizing the development of detonating gas on large platinum electrodes, having a surface of 8 square centimeters. His difficulty seems to have been to make the gas disappear, while ours was to make it appear. This difference results from the fact that the electromotor employed by De la Rive gave at most 50 alternations per second, while our dynamos give 100 as a minimum.

From this experimental study of the circumstances which affect electrolysis by alternating currents, we may deduce, along with the numerical laws of these phenomena, the general rules which ought to direct the utilization of these currents for this kind of application. —*Electrical Review.*

WOOD WOOL MAKING MACHINE.

WOOD wool is the name given to an article which, although it has been in use for some time on the Continent, has only recently been introduced into this country. It consists of very thin wood shavings, which

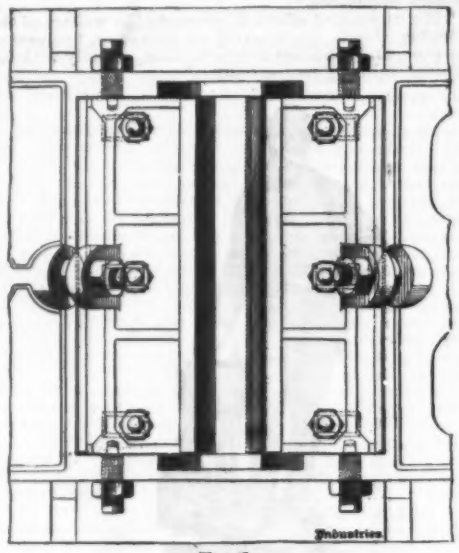


FIG. 1.

may be of any breadth, some of the samples we have seen being so narrow as to look like hemp. The coarser varieties are intended to be used instead of straw for packing goods, while the intermediate kinds are chiefly intended for stuffing furniture, such as chairs, sofas, mattresses, and pillows. Some of the finer varieties are also used instead of lint, and for various other hygienic purposes. We give herewith illustrations of a machine for making wood wool, which has been invented by M. Louis Arbey, of Paris, and has been patented by him in this country. Fig. 3 represents an elevation, and Fig. 4 a plan of the machine. A cast iron bed, resting on three feet, carries at one end the driving apparatus, and at the other a carriage for holding the wood and the slides which guide the cutting knives. The machine is driven by a strap, and at one end of the driving shaft is a fly wheel which carries a crank for giving the necessary oscillating motion to the knife frame, while at the other end of this shaft there is an eccentric which actuates the feed for the carriage holding the wood to be operated upon. The knives are vertical, and the frame in which they are held moves in slides, which are reversible, the top coming to the bottom, and *vice versa*. The knives are placed opposite to each other, so that one cuts when the slide moves forward and the other when it moves back again. One of the knives is a smooth blade, while the other is formed of a blade cut into teeth, so as to give a series of small blades separated by spaces of equal width. The toothed knife supplies shavings by cutting grooves in the face of the wood during the motion in one direction, and during the return the plain knife cuts shavings from the tops of the ridges which separate the grooves, these shavings being exactly similar to those cut by the other knife. In order to vary the angle of penetration of the knives according to the required thickness of the shavings, the knife holders are movable upon a vertical axis, and are easily adjusted by means of the nuts shown in Fig. 2. Figs. 1 and 2

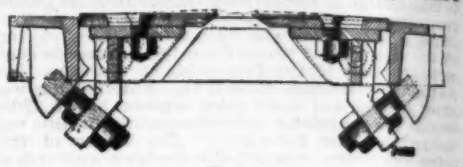


FIG. 2.

show in detail the knives and the method of mounting them. It will be seen that each knife is carried by a piece pivoted to the slide, and readily adjusted by means of the nuts acting against a lug. The blades are fastened to this piece by three bolts, and as the blades are slotted, they may be readily moved backward or forward. This facility for adjustment is of the greatest importance in machinery of this character. The machine is so constructed that the fineness of the shavings can readily be regulated as desired, by varying the velocity of the feed of the wood and the angle of penetration of the knives, the pitch or width of shaving being altered by changing one of the knives. The rest or headstock which carries the wood is made to travel on a transverse slide, and is moved forward by means of a screw, at the end of which is keyed a ratchet wheel actuated by a pawl at the end of a lever worked by the eccentric from the driving shaft, as shown in Fig. 5. The amount of feed is varied by raising or

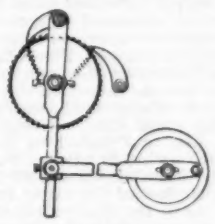


FIG. 5.

lowering the sleeve which connects the lever with the eccentric. It will thus be seen that the machine is at once simple and ingenious, and the samples of work which we have seen are of first class quality, being soft, elastic, clean, and free from that harsh, woody feeling which one would naturally expect, and which is actually found in the samples produced by the German, American, and other machines. In fact, they are so much like fiber, that the finer samples might easily be mistaken for hemp or horse hair. It is probably owing to fineness of texture that the material made by the Arbey machine in France is called "crin," or horse hair. Wood wool has already been introduced into several hospitals, where it is used for stuffing beds, and if made of certain woods, as pine, which contain gums or resins,

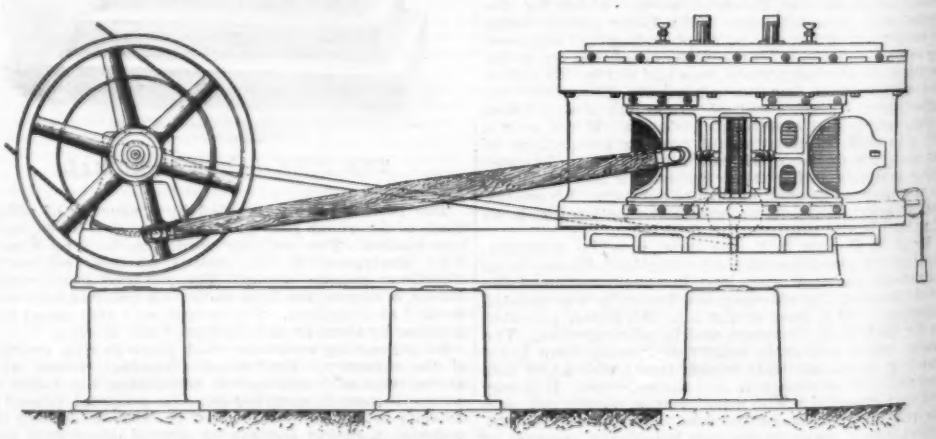


FIG. 3.—ELEVATION.

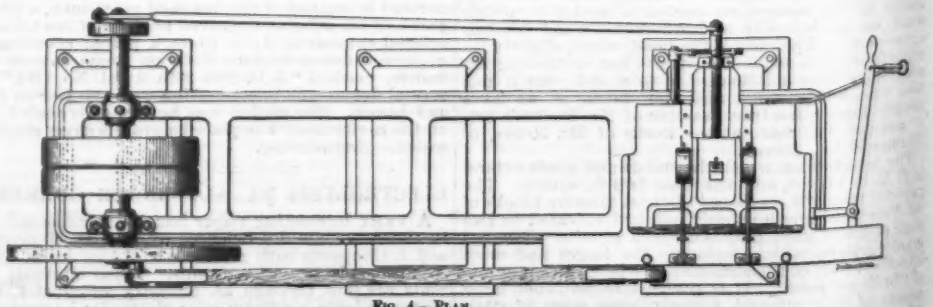


FIG. 4.—PLAN.

MACHINE FOR MAKING WOOD WOOL.

or if saturated with some antiseptic, it possesses numerous advantages from a medical point of view, in addition to its greater cleanliness than straw. Another advantage which this substance possesses over straw is that, on account of its softness, it is not liable when dry to break up into short pieces, nor will it sweat when used as packing for goods on long voyages. This material should prove very useful for emigrants' bedding, as well as for packing light and breakable articles. It has also been used for filtering purposes, and experiments which have been made in breweries as to its adaptability for filtering beer have shown it to give most satisfactory results. When used in the stable as a bedding for horses, it has the advantage of freedom from the smell of ammonia: and it can be burnt when used up, thus forming charcoal manure. A peculiar feature of wood wool is its extreme lightness; it is stated that 1 ton of this material is equal in bulk to 3 tons of hay or straw. —*Industries.*

HOW TO ANALYZE IRON AND STEEL.

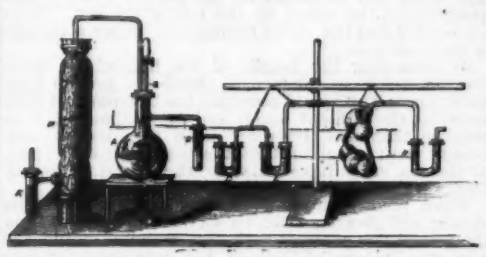
THE chemical analysis of a piece of iron or steel affords much information as regards its behavior mechanically. Much, however, as it explains, still this *such* is far from being satisfactory, as it utterly fails to account for discrepancies which occur in the mechanical behavior of two pieces of iron or steel of precisely similar chemical composition. It is not our intention in these articles to attempt to solve this problem, even supposing we were capable of so doing, which no one is; but rather to describe methods for the determination of the several constituents contained in the metals. The complete analysis of iron and steel for commercial purposes comprises the estimation of the carbon existing both in the free state, or graphitic, and also the combined carbon, silicon, sulphur, phosphorus, manganese, copper, and in some exceptional cases of the titanium, tungsten, chromium. For analysis the sample should be in a state of fine division, preferably in the form of drillings. This not being attainable with all specimens, such as white iron, the sample is in this case reduced to a coarse powder. Some chemists recommend that the drillings of the sample be treated with boiling ether under an inverted condenser, to extract the oil, etc., with subsequent drying at 100° C. We hardly think this necessary, if ordinary precautions be observed; but perhaps "prevention is better than cure."

The determination of the total carbon by combustion.—The estimation of the total carbon presents many difficulties on account of the large preponderance of iron over carbon, as also the numerous precautions, etc., which must be observed to obtain results which can lay claim to accuracy. As we have before stated, carbon may be present under two conditions, as free or graphitic and as combined carbon. At present we shall only deal with the determination of the total amount of carbon, regardless of the portions existing in the several conditions. When iron or steel containing combined and graphitic carbon is treated with hydrochloric acid, ferrous chloride is formed, the graphitic carbon being deposited as a black powder, while the combined carbon combines with nascent hydrogen, forming volatile hydrocarbons, which escape. If, however, we replace the acid by a metallic chloride, no evolution of hydrogen occurs, and the whole of the carbon is deposited, which may be collected, burnt in a stream of oxygen, employing either a dry or wet method of combustion, and the resulting carbonic acid, CO_2, weighed. This happens when the metal is treated with ammonium cupric chloride. The iron enters into solution, while the carbon, together with copper, etc., is deposited. The ammonium cupric chloride solution is prepared by dissolving 554 grammes of the crystals in 1,350 grammes of water. For analysis five grammes of the sample are weighed out into a beaker, covered with 125 cubic centimeters of the chloride solution, and gently heated to accelerate the action. On no account is the solution allowed to boil, as in all probability boiling will cause any silicon present to assume a condition which will greatly hinder the operation of filtering. If during disintegration the liquid becomes colorless, or nearly so, more of the chloride solution must be added. No hard and fast rule can be given as regards the time required to effect complete solution. The operator must therefore use his judgment, and be guided by the appearance of the residue. The residue consists of carbon deposited as a black powder, metallic copper, etc. The next step is to get rid of the copper. This is effected by making a further addition of the chloride, together with 60 cubic centimeters of hydrochloric acid, and digesting at a gentle heat. When all the copper has dissolved the solution is filtered, employing an asbestos filter, constructed as follows: A piece of glass tubing, about 6 in. long and ½ in. diameter, is contracted somewhat about an inch from one end, and this narrowed portion loosly plugged with glass wool. On the top of this is placed a layer of finely divided asbestos fiber, previously ignited, and washed with water as long as any of the fiber runs through. The residual carbon on the filter is washed first with hot hydrochloric acid and afterward repeatedly with hot water, until a drop of the washings after acidification with nitric acid gives no opalescence with a solution of silver nitrate.

The residue is now ready for combustion. We shall employ the moist method due to Ullgren, the principle of which is that chromic and sulphuric acids oxidize the carbonaceous residue left on treating iron or steel with ammonium cupric chloride into carbonic acid, CO_2. The apparatus necessary for the carrying out of the operation is shown in the cut. The carbonaceous residue, together with the asbestos filter, is transferred to the flask, A, of a quarter liter capacity, by carefully inverting the filter tube in the mouth of the flask, and gently blowing it out, of course washing in—employing the smallest quantity of water possible—any particles which may adhere to the sides of the tube. Connect the flask with the rest of the apparatus, and through the stop cock funnel, B, add 25 grammes of chromic acid crystals dissolved in a small quantity of water and 300 cubic centimeters of dilute sulphuric acid—two parts acid to one water. Close the stop cock immediately, and apply a gentle heat, so regulating as to maintain a constant evolution of gas. The carbon is immediately attacked by the acid, with the formation of carbonic acid, CO_2, and as it is evolved, escapes into D, containing a solution of silver sulphate in sulphuric acid, whereby it is deprived of any traces of chlorine, and from thence into the tubes, C, E, containing respectively calcium sulphuric acid and chloride, which dry the gas. Finally the carbonic acid gas enters the previously weighed bulbs, F, containing a solution of caustic potash—one part of the hydrate to two water—and here it is absorbed. Toward the completion of the operation, increase the heat as the evolution of gas slackens.

When the oxidation of the carbonaceous matter is complete, as judged by the appearance of white fumes in the flask, remove the source of heat and aspirate a gentle current of air—deprived of carbonic acid and moisture by causing it to pass through K, M, containing caustic potash and calcium chloride—through the apparatus, and when thoroughly cool disconnect the potash bulbs from the remainder of the system of tubes and reweigh. Any increase in weight will be due to carbonic acid, which contains 27·27 per cent. of carbon. A likely source of error is the danger of a portion of the water of the caustic potash solution contained in the bulbs, F, being driven off by the heated gas. This is guarded against by attaching a calcium chloride bulb, H, which is weighed both before and at the conclusion of the experiment, any increase in weight being deducted from the original weight of the potash bulbs. It is obvious that the apparatus must be thoroughly air tight, and, furthermore, that the reagents be pure. We advise that a blank experiment be made with the reagents employed to test their purity.

Determination of graphitic carbon or graphite.—As before stated, the above method determines only the total carbon present, irrespective of the portion present severally, as combined and graphitic carbon or graphite. To determine the graphite, three grammes of the iron or steel are weighed out into a beaker covered with 100 cubic centimeters of hydrochloric acid, and digested at a gentle heat for an hour or so. The insoluble portion, consisting chiefly of graphite, is collected on a weighed filter paper, repeatedly washed with hot water, dilute hydrochloric acid, a strong solution of sodium carbonate, then again with water, and finally with alcohol and ether. The filter paper and contents are removed to a water oven; dried at 212° Fah., and weighed. The filter paper, etc., is placed in a platinum crucible, the graphite burnt off at a strong red heat, and any residue (small quantities of silica and titanium) remaining are weighed, the weight of which, minus the filter paper ash,* is deducted from the graphite. This method



furnishes very good results, but in general practice it is not employed, the silicon and graphite being, as a rule, determined in one operation, which method we shall hereafter describe.

Colorimetric method for the determination of combined carbon.—Where a large number of determinations has to be made during the course of a day, the estimation of combined carbon by the combustion method above described is inapplicable, on account of the time occupied in its performance. A method, therefore, must be employed which, while being rapid and easy of execution, will furnish good results. Such a method is Egjertz's colorimetric test, based upon the color of the solution obtained upon dissolving iron or steel containing combined carbon in nitric acid free from chlorine. By therefore dissolving two pieces of steel, one containing an unknown, and the other, termed the standard, a known, quantity of carbon, employing an equal volume of acid for each, it becomes an easy matter to arrive at the amount of carbon contained in the unknown specimen by simply comparing the color of the two solutions. It is found that the method does not answer with specimens containing over three-quarter per cent. of combined carbon, neither with steels that have been hardened. Before results which can lay any claim to accuracy can be obtained, it is necessary to rigidly observe certain conditions, viz.: 1. The standard employment must contain practically the same amount of carbon as the specimen under examination. 2. It must be manufactured by the same process. It will not answer to employ a Bessemer steel for a standard to determine the carbon in a sample produced by the Siemens method. 3. The conditions, viz., the amount of acid and steel employed, temperature, time, etc., under which solution is effected, must be exactly similar. As is obvious, the employment of a standard steel in which the combined carbon has been carefully determined by the combustion process is necessary. The *modus operandi* of the method is as follows: 20 grammes of the standard and a like quantity of the sample under examination are weighed out and placed respectively in two dry test tubes of ½ in. diameter by 6 in. in length; 5 cubic centimeters of nitric acid 1·20 specific gravity, free from chlorine, is then measured into each tube, and when all action is at an end the tubes are placed in a beaker containing water maintained at boiling point and allowed to remain there for fifteen or twenty minutes. At the expiration of this time they are simultaneously withdrawn, any crust adhering to the sides of the tubes being removed by causing the solution to flow over it, and placed in a vessel containing cold water. When perfectly cold the standard solution is poured into a graduated glass tube, closed at one end, of 20 cubic centimeters capacity, divided into one-tenth cubic centimeters, the test tube washed out with a small quantity of *cold* water, the washings added to the main bulk contained in the graduated tube, the solution diluted with cold water until the volume occupied is a power of the carbon contained in the standard, and thoroughly mixed by closing the open end of the tube with the thumb, and inverting once or twice.

Example, with a standard containing 0·40 per cent. of com. carbon dilute to 5 cub. centimeters; 0·12 per cent. of com. carbon to 4 cubic centimeters. The solution of the steel being analyzed is now poured into a similar tube of a like caliber, the last portion rinsed in with a little water, and the solution mixed *without dilution.* If, upon comparing the two solutions, by holding them side by side with a piece of white paper behind them before a window, the color of the standard is lighter than the steel under examination, to the latter small quantities of cold water are added, mixing and comparing the colors with each fresh addition until the intensity of the tints are equal.

When this is attained, the volume it occupies is read off; the number of cubic centimeters multiplied by the power which the volume occupied by the standard solution is of the carbon it contains, will give the combined carbon in the specimen under examination. Example: The standard contained 0·40 per cent. com. carbon, the solution of which was diluted until it occupied a volume of 8 cubic centimeters, which is the fifth power of 0·40. The solution of steel being analyzed upon attaining similarity of tints occupied 7 cubic centimeters; the com. carbon present therefore is $7 \times 0·5 = 0·35$ per cent. Steel containing small quantities of carbon gives solutions more or less of a greenish tint; this, to a large extent, is remedied by employing a smaller quantity of acid—say about 3 cubic centimeters.

Determination of silicon.—Upon treating iron or steel with an oxidizing reagent, such as nitric acid, the silicon present is converted into silica, SiO_2. This forms the principle of the methods employed for its determination. Weigh out into a porcelain dish of 500 cubic centimeters capacity, four grammes of the sample, add 60 cubic centimeters of nitrohydrochloric acid, cover the mouth of the dish with a glass cover to prevent loss by spurting, heat gently on a hot plate or sand bath, and subsequently take the solution to complete dryness. Heat the dry mass until perfectly black, and allow the dish and contents to cool. Moisten the black residue with 60 cubic centimeters of hydrochloric acid, digest for some time, and evaporate the solution down until a crust commences to form on the surface, to dissolve which add a couple of drops of hydrochloric acid. A volume of water four times the bulk of the solution is now added to it, and the insoluble portion, silica, etc., collected on an English filter paper, the portions adhering to the sides, etc., of the dish being removed by means of a "policeman"—a piece of caoutchouc tubing at the end of a glass rod—and rinsed on the filter. The silica on the filter is washed, 1, half a dozen times with a dilute solution of hydrochloric acid, 2, with hot water until a drop of the washings gives no coloration when mixed with a little of a weak solution of sulphocyanide of potassium. The subsequent treatment of the filter paper and contents depends upon the absence or presence of graphite. In the first instance we will suppose that it is absent. The filter paper and contents, after washing as above, are transferred to a platinum or porcelain crucible, strongly ignited, allowed to cool, and the residual silica, SiO_2, containing 46·66 per cent. of silicon, Si, weighed. In the presence of graphite the *modus operandi* somewhat differs. The filter, etc., are placed on a shallow clay dish, and the paper burnt off at the lowest heat possible. When cold, the residue, consisting of silica and graphite, is weighed, replaced in the dish and again ignited, this time employing a heat sufficient to burn off the whole of the graphite. The silica remains and is weighed, which weight, deducted from the weight of silica graphite, will, as is obvious, equal the graphite.

A simpler and more rapid method is as follows: Dissolve four grammes of the sample, contained in a beaker, in 80 cubic centimeters of dilute sulphuric acid—one part acid to three water—and evaporate the solution until thick, white fumes commence to appear. When this point is reached, arrest the evaporation, allow beaker and contents to cool, add 60 cubic centimeters of boiling water, and heat until the white mass of ferrous sulphate has dissolved and nothing but silica and graphite remain, which collect on a filter; wash, etc, as before. The silicas obtained by the above methods should be perfectly white; but in the majority of instances they are more or less red, being contaminated with iron. This is especially the case with irons containing notable quantities of phosphorus, due in all probability to an insoluble phosphide of iron. Iron is not the only impurity, as although the silica may be perfectly white, it may still be contaminated to a considerable extent with titanium, if any be present in the iron or steel. As these impurities lead to inaccurate results as regards the amount of silicon present, they must be eliminated. This is effected by fusing the silica, contained in a platinum crucible, with six times its weight of acid potassium sulphate, the crucible, etc., subsequently placed in a porcelain dish and digested for some considerable time with cold water. When the fused mass has dissolved out, the crucible is well washed, withdrawn, and silica, now free from impurities, collected on a filter, well washed, ignited, etc.

The following rapid method, due to Mr. Jno. Parry, F.C.S., furnishes results, especially with pig irons, which, although not absolutely accurate, are for all general purposes sufficiently near. One gramme of the sample, if a pig iron, or four grammes of a steel, are placed in a shallow clay dish and heated in a muffle to a bright redness. The temperature employed must not be too intense, otherwise the mass of iron will stick to the dish, and great difficulty will be experienced in dissolving it when subsequently treated with hydrochloric acid. The heating is continued for half an hour, at the expiration of which time the dish and contents are withdrawn and allowed to cool. When cold the mass of iron transferred to a beaker containing 60 cubic centimeters of hydrochloric acid, and the solution gently heated until all besides the silica, and perhaps a little graphite which has escaped burning, is dissolved. The residual silica is collected on a filter, washed, etc.—*The Engineer.*

* Several of the constituents of iron and steel being present in such minute quantities, an increase in weight amounting to two milligrammes makes a vast difference in the resulting percentages. It is therefore absolutely necessary to determine the ash in the filter paper employed, and to deduct it from the weights of the resulting precipitates, residues, etc.

THE acquisition of learning without study is like the acquisition of wealth without labor. It is as necessary for the mechanic to study out his problem when it comes to him to be studied as it is for him to finish his task by his handicraft.

[Continued from SUPPLEMENT, No. 660, page 10548.]

GEOLOGY.

By ARCHIBALD GEIKIE, LL.D., F.R.S.

THE CRUST OF THE EARTH.

I. Proofs that Parts of the Crust have been Pushed up.

WE have now completed the first part of the task which was proposed in an earlier lesson—to find out what the materials are of which the great stone floor of the earth is made. We have learned something about three great classes of rocks which form that floor—how they were made, and where they are to be seen. But while learning these facts about the earth, we have seen that the rocks are not a mere thin covering like a wooden floor below which we should come to something quite different. We cannot get down beneath the rocks. Deep as the deepest mine the same kind of rocks may be found which elsewhere exist at the surface. It is always through rock of some kind that we must descend as far as we can penetrate into the bowels of the earth.

This solid rocky outer part of the earth on which we live, into which men sink mines and out of which springs arise, is called the earth's crust. This name came into use when people supposed that all the inside of the planet was an intensely hot liquid mass with a cool and comparatively thin crust outside. A great deal of dispute has arisen as to whether the main mass of the inside of the earth is liquid or solid; but those who dispute, whatever their view may be, agree to use this phrase, the earth's crust, as meaning that part of the earth which men can observe from the top of the highest mountain to as far below the deepest mine as they can reasonably infer what the rocks must be.

The rocks of which this crust consists belong mostly to the sedimentary series, a large number to the organic series, and a smaller but still considerable proportion to the igneous series. In Britain, for example, if we could put all the different series of sedimentary and organic rocks together, one above another, in the order in which they were deposited, they would form a mass at least ten or twelve miles thick. Out of such materials the solid earth is built up as far down into its depths as man has been able to descend.

But from what has been stated in previous lessons it is clear that many of these rocks are not now in their original positions. Our quarry, for example, told us how the rocks in which it lay had once formed a part of the sea bottom. Then again the coal seams, buried so deep in the earth, were once verdant forests or jungles at the surface. How could a sea floor become dry land, and how could a forest on the surface of the land come to be covered by hundreds of feet of solid stone?

Let us begin by considering how it is that a portion of the floor of the sea can be changed into good dry land. And in order to follow the change as clearly as possible we shall choose of the simplest examples, and one moreover which many of us may have the opportunity of verifying for ourselves.

Round the coast line of some parts of the British Islands there runs a low flat terrace bounded by the sea on the one hand and by a cliff or inland slope on the other. Seaport towns have been built upon this terrace, such for instance as parts of Glasgow, Greenock, and Leith. It is so level that roads run along its surface for miles among corn fields, meadows, and villages. You may gather some notion of its general appearance from Fig. 33, which shows how flat it is and how little

FIG. 33.—View of a Raised Beach.

elevated above the sea at its outer edge. Along its inner margin there often rises a line of cliff pierced with caves, as represented in the drawing. If you were standing on some part of this terrace and looking along its level surface as it winds in and out against the cliffs and slopes of the land, would not the idea of an old coast line at once suggest itself to your mind? You can without difficulty picture the sea covering that terrace and beating against the base of those cliffs and slopes.

Could you prove this fancy of yours to be anything more than a fancy? Let us see. Cross to the inner margin of the terrace and consider attentively the line of caves you find there. How did these excavations come to be drilled into the solid rock all along the same line and exactly at the same level, so that the floor of each of them should just open upon the flat terrace? Suppose that you visit one of these caves. Festoons of ivy and honeysuckle hang perhaps in tangled luxuriance about its mouth, and you may have to force your way through a brushwood of strong briers. But you gain at last the floor of the cave, which you find to be roughened with rounded, water-worn stones. The roof is partly hung with ferns, mosses, and liverworts, and the sides too have their drapery of green. But the bare rock appears abundantly, and you notice that it has been rubbed smooth, and has the same water-worn character as the stones under your feet. Now go outside and look at the bare rocks of the cliff above; you see how rough and sharp edged they are, as from time to time they split up under the influence of the weather. The walls of the cave have been ground smooth from one cause, the face of the cliff has been made rough from another.

The explanation of this difference will be apparent if you remember what takes place where a sea cliff of hard rock has its base washed by the waves. You have seen how the rocks, wherever the waves can reach them, are worn smooth by the ceaseless grinding of the gravel and stones to and fro. And every cave into and out of which the waves drive the gravel is ground down in the same way. A single forenoon spent on such a coast line gives you a lesson you can never forget as to the way in which rocks have their surfaces smoothed by the waves. But all which lies above the reach of the breakers comes under the influence of other forces. Rain, frost, and springs combine to make

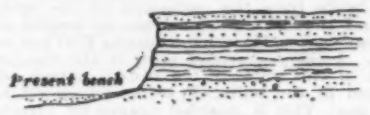


FIG. 34.—Section of a Raised Beach.

the cliff crumble down, and fragments to split off from its face, so as to give that rough, angular appearance which contrasts so well with the water-worn rocks below.

After having observed in this way what is taking place now along a sea cliff, you can hardly doubt that the line of cliff which rises from the inner margin of our terrace was once a sea cliff too, with the waves beating against its base and boring that line of caves there, as they are still doing elsewhere. The line of that cliff thus becomes in your mind the line of a former sea shore.

But further proofs of the former presence of the sea present themselves if you put questions to the terrace itself. Dig beneath the surface of that terrace anywhere, and what do you find it to consist of? Sand and gravel, sometimes with abundance of shells. Look at the outer margin of the terrace where the sea is gradually cutting it away, and you find there that the sand and gravel are laid down in layers, just as they are on the beach below, and that the shells belong to the common kinds which are washed up by every tide upon the sands. You discover that in truth the terrace is simply an old beach, and that the sea must have laid down the materials of the terrace when it was scooping out the caves at the foot of the cliff. Thus the terrace and the caves combine to prove a change in the coast line.

By measuring the height of the floor of the caves and the height of the terrace above the present high water mark, you would ascertain the difference of level between the present beach and the old one. Let us suppose that this difference is in the present case twenty feet; it is plain that the land must have risen, or the sea must have sunk, to the extent of twenty feet.

When you watch the restlessness of the sea, with its ebbing and flowing tides, its waves and currents, and then when you contrast with this ceaseless motion the calm steadfastness of the land, you may naturally suppose that, in any changes of the relative position of land and sea, it is much more likely that the sea should have shifted its place than that any alteration should have happened to the land. But reflect for a moment on what would be involved in a change in the sea level at any place. If I deepen the bottom of one end of a pond, does the level of the water fall just over that part where I have been at work? Assuredly not; the level of the whole pond is lowered. In the same way, if I empty a quantity of stones and earth so as to make one part of the pond very much shallower, do I raise the level of the water only over that part? By no means; the influence of what I have been doing extends through every part of the pond, and the level of the water is uniformly raised over the whole.

Now, instead of the pond, think of the great ocean, which is only an enormously large continuous sheet of water. You see that an alteration of its level in one region must necessarily extend over the whole globe, until the same general uniformity of level is restored. If the sea has sunk from our terrace (Figs. 33, 34) to the extent of twenty feet, there must have been at the same time a general lowering of the sea level all over the world. But is it so? How would you set about to ascertain this point?

Plainly if the terrace has been left by a sinking down of the bed of the sea, you should meet with a corresponding terrace all over the globe. But you would not require to travel far before you ascertained that no such universal terrace is to be seen. Even around the

FIG. 35.—Terraces (Raised Beaches) of the Alten Fjord, Norway.

coast of Britain you would find enough to show you that there has not been any general subsidence of the ocean. Throughout a great part of the margin of our island no terrace occurs at all. Only in certain districts is such a terrace to be met with, and its height is not always the same.

Sometimes a series of terraces may be seen rising one over another, each marking a former coast line. In the north of Norway they occur in great perfection (Fig. 35), up to heights of several hundred feet. They look perfectly horizontal to the eye, yet when they are measured accurately they are found sometimes to rise toward the upper end of the long inlets on the sides of which they run, so that a terrace which at the seaward end may stand at a height of 80 feet above the sea is as much as 90 or 100 feet at the landward end. Now such a difference of level in a short distance proves that something else must have taken place than a mere subsidence of the sea, for had that been the cause of the terraces being left, they should all have been as horizontal as the surface of the sea itself, and at least traces of them should have been found at corresponding heights in our own country and all over the world.

Strange as it may seem to you, it is nevertheless true that it is the land which rises, not the sea which sinks. If that be the case, it is easy to see how there should be terraces in some countries and not in others, and how the same terrace should vary in height at different parts of its course. For the land may have been pushed up at one place and not in others, and more at one place than in another. The old sea terrace (Fig. 33) is called a raised beach, because it consists of gravel, sand, and other beach deposits, which have been raised above the level of the sea. Every such raised beach points to a former sea margin, and to an elevation of that sea margin into dry land. Where a great many terraces occur one above another, as in Norway (Fig. 35), they show us how the land has been raised up at intervals for a long period, the time when the land was stationary between two upheavals being marked by a terrace or raised beach. Of course the highest terrace must needs be the oldest, and for that reason is often less perfect than the newer ones, having suffered more from the various forces, such as rains, frosts, and streams, which are so busy in making the surface of the land crumble away.

In some parts of the world we can detect the ground in the very act of rising. In the southeast of Sweden, for example, rocks have been marked at the place where high water reached them, and in the course of years have been found to be considerably above their former level. From observations of this kind it has been inferred that the land there is rising at the rate of about two or three feet in a century. This appears to be but a very slow movement, too slow to be appreciated, except by careful measurement; and yet if it were to go on for another thousand years, what is now the beach would have risen to a height of twenty or thirty feet above the sea level.

You see, then, that the upraising of the bottom of the sea, strange as it may seem to us, is not entirely a thing of the past. It is going on slowly at the present time in several parts of the globe. And just as the coast of Sweden is rising with no violence or shock, so in old times the upraising of the sea bed into dry land may have been a gentle and quiet process.

The rocks of every country furnish abundant evidence that the sea bottom has again and again been elevated into land. This evidence is furnished, as you now know, chiefly by the remains of corals, star fishes, shells, and other sea creatures, which may be traced embedded in the rocks. The height at which these remains are found affords us some idea of the extent of the elevation. The shells of our raised beach indicated a rise of only some twenty feet. But if you found such sea shells at a height of twenty thousand feet, they would prove that the bed of the sea had been elevated at least to that extent. By this kind of evidence it can be shown that by much the greater part of the dry land has been raised, piece by piece, out of the sea, and that the movements have been far from regular or uniform, seeing that some parts have been upheaved to a much greater height than others.

II. Proofs that Parts of the Crust have Sunk down.

We have now traced out some facts which show that the surface of the globe has from time to time been pushed up, so that parts of the sea bottom have become dry land. But other movements of exactly an opposite kind have turned parts of the land into the bed of the sea. Let us follow some of the evidence for these depressions, and take, as before, our illustrations from places which are easily visited, and in our own country.

Along some parts of the coast line of Britain, as, for example, on the coasts of Devon and Cornwall, and on that of the Firth of Tay, a very curious and interesting feature occurs between high and low water mark. From the flat sandy surface of the beach a number of dark stumps may be seen sticking up, which, on closer examination, prove to be the lower ends of trees. Scraping away the sand of the beach, you meet with dark loam or earth, out of which the tree stumps protrude, and from which you may pick up hazel nuts, leaves, twigs, and, now and then perhaps, the wing case of a beetle or the bone of some land animal. As you trace stump after stump along the beach, you see

FIG. 36.—Section of a Submerged Forest.

that they are all in the usual upright posture in which trees grow. The dark earth in which the tree roots spread is clearly an ancient soil, in which to this day may be gathered the very leaves, twigs, and nuts which fell from the trees, and fragments of the insects which lived amid their decaying timber. These stumps on the beach are evidently parts of an old forest or wood.

But could the trees ever have grown where their remains are now to be seen? By no means. The hazel, birch, alder, and oak, of which the stumps mostly consist, would be killed if their roots and trunks were to be permanently submerged in the sea. You never see any of these trees growing below tide mark now, and you cannot suppose that they ever did so. If the trees on the beach must have grown where their remains still exist, and if they could not have grown up in the sea, then, either the sea must have risen up so as to cover them, or the land must have sunk down so as to submerge them. But we have already learned that in all such cases of change of level we cannot believe that the sea alters its level to any appreciable extent, so

that we must conclude that the submergence of the old trees has been due to a sinking down of the land. These submerged forests, therefore, are to be regarded as evidence of subsidence of the earth's surface, just as the raised beaches are taken as proofs of upheaval.

You can understand that it must be more difficult to trace evidence of ground having sunk than of its having risen in level. Because when any district has gone down below the sea, the waves gradually obliterate all trace of the former land surface, as they are now washing away the submerged forests; while, on the other hand, when the bed of the sea is turned into dry land, such traces as raised beaches and old sea-worn caves remain to mark the space which the salt water once covered.

In different parts of the globe it has been observed that the sea appears to be gradually rising upon the land. In reality it is the land which is there sinking below the sea. For example, the southern part of Greenland for several hundred miles has during the last few centuries been slowly subsiding, so that rocks which once lay above the limits of the tides are now submerged, and the dwelling houses of the inhabitants have had to be shifted further and further inland.

Other proofs of the same fact have already been referred to in the foregoing lessons. The beds of coal, for example, which once flourished as green forests at the surface are now found buried deep within the earth. By what process did they get there? Let us return for a while to the coal pit before referred to.

In many parts of Britain the coal pits are more than a thousand feet deep. And yet down at the bottom of each of these pits lies the coal seam, which we have found to be a buried swamp or jungle. If you could look at all the rocks which have been cut through in making the long shaft of the pit, you would usually find among them other coal seams than the one at the bottom. In fact, several seams are sometimes worked for coal at different levels in the same pit. You will understand their position from the section in Fig. 37,

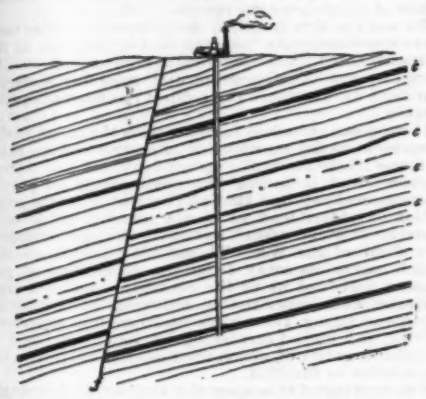


FIG. 37.—Section of the Strata in a Coal Pit. *c*, coal seams; *f*, a fault or fracture of the rocks.

which shows how the rocks lie one above another in one of these pits. You notice that the seam down to which the shaft has been sunk is the fifth of the series, but it is chosen in the meantime, probably because it is a better kind of coal than the other four seams above it, and therefore brings more money in the market.

In such a section as that in Fig. 37, which shows only what may be met with in any coal field, we see that the strange revolution whereby a green waving forest has been buried underground must have happened not once only, but many times; for every separate coal seam was evidently at one time a verdant plain, open to the sun, and bright with many a graceful tree and fern. And still more, besides the evidence of the coal seams, upright stems of trees, now turned into stone, are sometimes found standing in the sand-

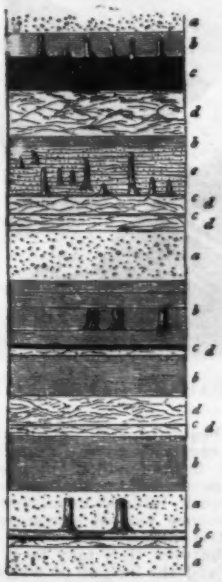


FIG. 39.—Section of a part of the Cape Breton Coal Field, showing seven ancient soils, with remains of as many forests. (R. Brown.) *a*, sandstone; *b* and *e*, shales; *c*, coal seams; *d*, underclays, or soils.

stones and shales, in the very position in which they grew with their roots even yet embedded in the ancient soil. (Fig. 38.)

The lowest strata are of course the oldest. Hence the undermost coal seam must have been buried before the later forests could spring up on its site. It grew probably in a wide, marshy plain, which when the ground sank down became a wide sheet of water. Sand and mud were carried into this water, and laid down upon the submerged forest. These sedimentary deposits may now be traced in the beds of sandstone and shale which overlie the coal seam. The sand and mud brought into the wide and shallow sheet of water might in the end fill it up so that at length, as the muddy bottom rose to the surface, a new mass of vegetation would take root and form as luxuriant a growth as the buried forest had done. But after this had taken place the downward movement of the ground again showed itself, for this second forest was carried beneath the water and covered with renewed accumulations of sand and mud.

Hence we learn that our coal fields were formed in regions which were sinking, and that the downward movement was not continuous, but went on at intervals. That it must have been prolonged through vast periods of time is apparent from the fact that the strata of the coal fields are many thousands of feet thick, and must hence have needed long ages for their formation.

Two facts are now very clear to you about the crust of the earth—1st, it has often been pushed outward, so as to rise above the level of the sea; and 2d, it has also often sunk inward, so as to carry parts of the land deep beneath the sea level. But it could not undergo these movements without suffering other changes, which will be considered in the next lesson.

III. Proofs that the Rocks of the Earth's Crust have been Tilted, Crumpled, and Broken.

If you think about the movements described in the two previous lessons, and consider how often the crust of the earth must have been pushed up or let down, you will not be surprised to find that the rocks have not only been shifted up or down, but have been crumpled up and broken across. Hence the crust of the earth, instead of being made of regular layers one above another, like the coats of an onion, has been so squeezed and fractured, that in many cases the bottom or oldest rocks have been pushed up far above the newest. Let us clearly understand how this statement can be made out; and for that purpose we shall begin, as before, with the simplest case.

Look back again for a moment at the view and section of the raised beach in Figs. 33 and 34. The old sand and gravel beds have there unquestionably been raised up above their former level, but they have not otherwise been disturbed. They still lie out horizontally as they used to do. But would this be the case everywhere along that terrace? You remember that we ascertained that the terrace cannot be traced all round the country, that it dies out in certain directions, and consequently that the elevation which produced it was not universal, but local. Now, it is clear that though the upheaved tract rose so uniformly that the raised beach may retain the same level for many miles, still, between the horizontal strata which were upraised and those which, lying outside of the elevated district, remained unchanged in level, there must be an intervening space, longer or shorter, where the strata slope down from the raised to the stationary ground.

To make this clearer, suppose by way of illustration that we place upon a table a number of sheets of cloth to represent the different strata with which we are dealing. The cloths, like the strata, lie there horizontally. But if we push them up anywhere, they will be found to slope away from the elevated to the unmoved part. Put a flat plate, for instance, underneath them, so as to raise a considerable surface. Over the flat surface of the plate the cloths are flat, as they are in our raised beach, but from that upraised area they slope down to the undisturbed parts around. So that you see how a local elevation, even though it may raise up strata over a wide district without disturbing their flatness, must yet give rise to an inclination of the strata round the outskirts of the movement.

Wherever, therefore, strata are pushed up or let down more at one place than at another, without being actually broken across, they must be thrown into an inclined position. Now this uncqual and irregular kind of movement has taken place many times in every quarter of the globe. If you look at the stratified rocks in most parts of this and other countries, you will seldom find them quite flat—usually they are inclined, sometimes gently, sometimes steeply, so that they have not only been upheaved out of the sea, but have been moved irregularly and unequally.

In the quarry which we formerly visited, the strata were horizontal. But in many quarries you would find them turned up as in Fig. 38*a*, where the right hand por-

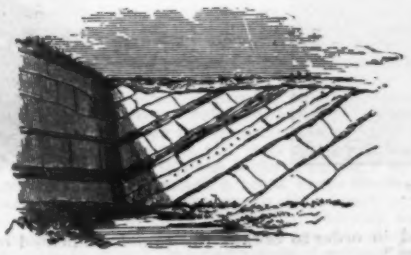


FIG. 38*a*.—Inclined Strata.

tion has gone up (or the left hand parts have gone down) more than the others. In some places, indeed, you will meet with the rocks so tilted up as to stand fairly on end (Fig. 39), like a row of books on a shelf. As they are made of sediment which gathered on a flat or gently sloping bottom, you see at once that they never could have been placed on end originally, but have been tilted into this position by underground changes. But this is not all. If, when the cloths were lying flat on the table, you had squeezed them from either end, they would have been thrown into crumplings. (Fig. 40.) In the same way, during the movements by which the strata have been raised up, a great deal of similar crumpling has taken place. In Fig. 41, for instance, the hard rocks are shown to have been twisted and folded over as if they had been mere layers of cloth. How enormous must have been the pressure to which they were exposed before they were squeezed into these shapes!

One difference between the cloths and the strata will occur to you. The one are soft and pliable, the others hard and rigid. But we may even make the most unyielding rocks to bend a little, and if this can be done

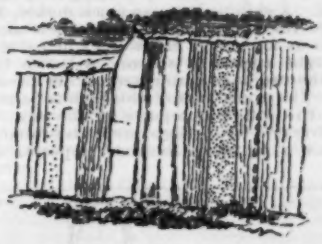


FIG. 39.—Vertical Strata.

even with the comparatively feeble force which man can employ, we may perceive how, under the enormous pressure which they underwent in the depths of the earth before they were upheaved, the rocks should have been crumpled up like mere pliable layers of cloth.

Still there must sometimes have been a point beyond which they would rather break than bend any further.

FIG. 40.—Cloths Crumpled by Pressure.

Cracks would then be formed, and the strata would be thrust up or made to sink down. You see one of these cracks, or faults, as they are called, at *f* in Fig. 37, where the coal seams and the strata between them have been broken across—those on one side of the fracture being now found at a lower level than those on the other. Dislocations of this kind are of such frequent occurrence that the whole surface of the earth may be looked upon as a network of cracks. They

FIG. 41.—View of Contorted Strata.

greatly interfere with the working of coal mines, as shown in Fig. 37, where the galleries which are driven along the coal seams from the pit toward the left hand will need to be altered where the coal is cut off by the dislocation, *f*.

It has often happened that into the cracks thus formed masses of melted or igneous rocks from the interior have been pressed, so as to rise up and intersect the other rocks. In the section in Fig. 42, for example, two such dislocations have occurred in a series of stratified rocks, so that three different groups, A, B, and C,

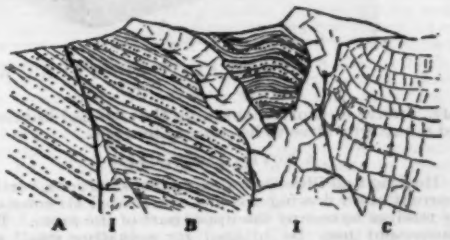


FIG. 42.—Section of Igneous Rock forced up into Cracks and Fissures of the Earth's Crust.

have been displaced. Into one of these cracks a mass of igneous rock (I) has forced its way for some distance. But in the other, that to the right hand, a much larger body of melted rock has risen, so as completely to separate the stratified rocks, B and C, and not only so, but to break through the group, B, ascending even to what is now the surface of the earth.

(To be continued.)

CURIOUS INVENTIONS.

WE give from *La Nature* the following:

A NOVEL ANEROID BAROMETER.

THE ordinary aneroid barometer is provided with a needle which revolves around its axis and indicates the barometric pressure by passing over the divisions of a dial. A skillful Parisian clock maker, Mr. Ledret, has given the aneroid barometer a new aspect which seems to us attractive and worthy of being described. A very light mica disk is connected with the mechanism of the ordinary barometer, and revolves about its center. The upper part of this disk is painted so as to imitate the different aspects of the sky. When the barometric pressure is high, and it is probable that the weather will be fine, a blue sky appears. If the pressure is very low and the weather is stormy, there is seen, on the contrary, a dark sky loaded with *nimbi*. The movable sky revolves under a glass upon which is painted a landscape, and which is left plain at the upper part, so that the different aspects of the sky can be seen. At the top, as shown in the figure, a small black arrow is engraved on the glass to show the pressure in millimeters of mercury, as in ordinary aneroids.

A BAROMETER WITH MOVABLE SKY.

AN ELECTRIC PAPER WEIGHT.

The paper weight herewith illustrated is a reproduction, under an industrial form, by Mr. Trouve, of a toy that was brought out ten years ago. It consists of an electric motor of simple form that gives seeming life to artificial birds, insects, etc., placed under a plano-convex lens, the whole resting upon a base that contains an electric generator. This latter consists of a hydrochlorate of ammonia or moist sulphate of copper pile inclosed in a hermetically closed ebonite receptacle. When the weight (No. 3) is placed upon its base (No. 2), a communication between the two is at once established through the intermedium of metallic plates that project slightly from the base. The bird or insect flaps its wings and produces a peculiar rustling sound that in a certain measure gives the illusion of life. When the paper weight is removed from its base, all motion ceases.

It is said that a certain very sensitive lady accused Mr. Trouve of cruelty, thinking that he had imprisoned a butterfly alive to let it die of hunger.

AN ELECTRIC PAPER WEIGHT.

A NOVEL LAMP SHADE.

Heating and illuminating apparatus induce a vertical current of air flowing upward, the heated air constantly tending to occupy the upper part of the room. This movement may be utilized for actuating small and light apparatus suspended from a wire or resting upon the point of a needle. We have often seen specimens of these little devices arranged over a stove by the employes in the offices of the Paris Omnibus Company. Some of these devices were quite ingenious, and moved the arms and legs of grotesque paper figures. Every one, too, knows the small mica helix that is designed to be placed above lamp chimneys. It is more difficult to utilize the current of air that circulates against a lamp chimney, the heating being quite feeble at this place, and the current being consequently less powerful. A skillful lamp shade manufacturer, Mr. Defaucheux, has nevertheless succeeded in turning it to account in a very ingenious manner. To this effect, he makes use of a lamp shade upon which he mounts a small wheel of light and delicate structure provided with vanes. The air imprisoned by the shade, which to this effect is provided with a cap (Figs. 5 and 6), can escape only by passing through the vanes of the wheel, and the latter is thus revolved with more or less speed, according to the nature of the lamp employed. To the external part of the wheel is glued a transparent sheet of paper, carrying, in the direction of the radii, bands painted in different colors. Cardboard disks provided with open-work designs of various patterns are placed, one after another, on small hooks arranged above the wheel, and the colored radial bands then produce figures that have a most charming effect.

A NOVEL LAMP SHADE.

In the engraving, Fig. 1 represents the wheel in motion, and Fig. 2 at rest. Fig. 3 shows the details of the wheel. Fig. 4 represents the open-work disks, and Figs. 5 and 6 the caps for quickening the draught.

THE MUSICAL PAPER CUTTER.

One of our readers, Mr. L'Esprit, communicates an interesting acoustic experiment on the subject of the vibration of rods. A simple paper cutter suffices to perform it with. Our correspondent has been obliging enough to send us a Japanese paper cutter prepared by him, and which we reproduce accurately in our figure. Mr. L'Esprit writes as follows: "By means of a paper cutter struck against a hollow piece of furniture (the angle of a desk for example), one can produce all the sounds of the gamut. The place where it is necessary to strike in order to obtain the desired sound can be ascertained by experiment, and various airs can be easily played with this primitive instrument. I send herewith a cheap paper cutter on which I have marked the notes that it produces on striking. As it is necessary that the vibrating rod shall always have the same length, I have marked with a pen, above the hole, the place where the paper cutter should be held in order to obtain the sounds indicated on the edge."

THE MUSICAL PAPER CUTTER.

THE TRUE RELATION OF PHYSICAL SCIENCE TO RELIGION.

By HENRY MORTON, President of Stevens Institute of Technology, etc.

ALTHOUGH it is entirely my opinion that the *Stevens Indicator* cannot afford space for the adequate discussion of so large and important a subject as the relations of religion to physical science, yet, in view of the fact that many pages of the last number have been occupied by an essay on this subject, containing, in my opinion, a number of mistakes as to facts and conclusions, and likely to mislead readers unfamiliar with the matters referred to, I feel it a duty to offer a very brief statement of certain facts which may put readers of the *Indicator* on their guard and so tend to the correction or prevention of erroneous impressions. My desire for brevity, as well as other considerations, leads me to avoid any attempt to criticise the article referred to in detail, or to point out its specific errors, and I shall confine myself to the statement of a few points, and some references to reliable treatises on the general subject concerned, leaving the reader to apply the facts and suggestions to the matter in hand.

The fundamental doctrines of religion, such as those of immortality, the existence of a divine ruler of the universe, and the moral responsibility of man, can, in the nature of things, neither be established not refuted by physical science.

The two subjects are more utterly unrelated than those of chemistry and mathematics, and it would not be more unreasonable to say that the principles of analytical geometry had been rendered doubtful by the developments of modern chemistry than it would be to say that the foundations of religious doctrine have been undermined by the developments of physical science.

All that physical science can do either for or against religion is, at most, to furnish, or not to furnish, indirect and collateral support, in the shape of analogies and parallels between the facts and laws of the physical universe and what religion teaches about the attributes of the divine ruler; or to supply us with suggestions and indications which may in a general way make for or against the doctrine of immortality and of moral responsibility.

In either case, however, such analogies, parallels, suggestions, and indications can neither establish nor refute the doctrines of religion; so that we see, at the very outset, that theology has nothing to fear from any possible development of physical science, nor have intelligent theologians, so far as I have observed, ever expressed or exhibited any such fear.

Passing, however, from this general and preliminary consideration, let us inquire whether the modern developments of physical science, so far as they bear upon the subject, tend to support the fundamental doctrines of religion, or the reverse.

To answer this question fully would require vastly more space and time than can be here devoted to that purpose, and I must therefore confine myself to a few words by way of suggestion, and refer my readers to standard works, where the subject has been adequately treated.

If we make ourselves familiar with the most modern theories as to the constitution of matter and the nature of forces (these being the groundwork of the material universe, and including the entire range of physical science), we shall find that all theories as to the constitution of matter lead us to the assumption of supermaterial existences (such as the frictionless incompressible fluid of Sir Wm. Thomson's "vortex atoms"), which carry us away from the conditions of gross matter and lead us to the contemplation of a supermaterial and imperishable universe, co-existing and interpenetrating the visible and tangible universe of matter, and indeed furnishing an immaterial and imperishable entity of which the material universe is only a condition or function.

The bearing of this upon the subject of immortality and of spiritual existences I cannot here develop, but must refer my readers to the remarkable work by Clerk Maxwell and P. G. Tait, entitled, "The Unseen Universe, or Physical Speculations on a Future State," where this subject is fully developed by these very eminent physicists, who, in this work, show that the reasonable deductions from the most modern theories concerning matter and force are in accord with a belief in a future state, the existence of spiritual beings, and the rule of a divine providence.

I may mention in passing that the key note of this book is a passage from Dr. Thos. Young, quoted in the last number of the *Indicator*, and there characterized as "absurd." It is also quoted in full in this book and is characterized by these eminent living physicists as "this most beautiful and comprehensive passage." It is hardly necessary to say that the writer in this journal quite misunderstood the passage in question, which by no means implies that matter by attenuation may become spirit, but does mean that there are known to physical science various existences, such as the so-called "electric fluids," the "luminiferous ether," the causes (whatever they may be) of gravitation and other forces, and the like, all of which radically differ from matter and form an ascending series in their supermaterial qualities, which naturally leads us on toward a final term which may well be a spiritual and immortal essence.

In the second place, directing our attention to force, which, as before pointed out, is the other factor which, with matter, makes up the physical universe, let us examine all that modern physics, from the time of Newton down, has done toward the explanation of the nature of gravitation, the most familiar of the forces.

In this study we are struck by two things. First, the entire failure to produce any theory which can

stand the test of close analysis. A great number of the most eminent mathematicians and physicists, such as Faraday, Seguin, Lame, Challis, Tait, Croll, Guthrie, and Maxwell, have worked on this problem with the sole result of disproving each other's or their own earlier theories, without any success in evolving a single hypothesis which will account consistently for the various facts as to gravitation and its actions known to all.

In fact these efforts fully confirm the prevision of La Place, who says in his "Mechanique Celeste": "The nature of that singular modification by means of which a body is transported from one place to another is now and always will be unknown. It is denoted by the name of force." The second striking feature of these investigations and discussions is that they bring prominently before us certain characteristics of this force which are very suggestive in the present connection. Thus we know that gravitation acts instantly and always in all parts of the universe, or is *omnipresent*. It is also instantly conscious of all changes of configuration among the bodies concerned, without any loss of time (as occurs with light) in the transmission of its influence. We *see* a star, not where it *is*, but where it *was* when the light left it; but gravity draws the star from where it is and not from where it seems to be. In view of this, we might well say that gravitation was *omniscient*. And in like manner, beholding it as the unexhausted controller of the infinite stars and planets, suns and systems of the universe, may we not well call it *omnipotent*, and likewise *eternal*?

Having in view the seemingly unfathomable mystery of its nature and these above mentioned characteristics, are we not almost necessarily led to the theistic view which regards it and all other forces as manifestations of the divine will, which, having created the universe, thereafter sustains it with such an all-pervading influence that, without his knowledge, "not a sparrow falls," and "in whom we live and move and have our being," and not we only, but the whole universe?

What I have said above on this subject is but the most meager suggestion of what might be said, and I will not attempt to develop it further here, but only refer to an admirable paper on "Kinetic Theories of Gravitation," by W. B. Taylor, in the Smithsonian reports for 1876, where the greater part of this matter is most ably treated.

Enough has been said, I think, to show that physical science is at least in no position of antagonism to religion and theology, and I would only further recommend to the attention of all the work entitled "Lessons from Nature," by St. George Mivart, Ph.D., F.Z.S., etc., Prof. of Biology at the University College, Kensington, and Lecturer of Zoology and Comparative Anatomy at St. Mary's Hospital, London; published by D. Appleton & Co., New York. Also a little book sold for 25 cents, but admirably gotten up, with good print and paper, entitled, "Scientific Sophisms," by Samuel Wainwright, D.D., published by Funk & Wagnalls, New York.—*Stevens Indicator*.

LONDON SEWAGE.

ON July 24, a party of members of the Society of Engineers were enabled to examine the new precipitation works at Barking Sewage Outfall, constructed by the Metropolitan Board of Works. At the present time the whole of the sewage of the metropolis north of the Thames is conveyed to Barking Creek by three culverts, each 9 feet high by 9 feet wide, and is, in the first instance, delivered into a covered reservoir, divided into four compartments, and altogether extending over an area of 9 acres. The sewage is stored in this reservoir during eight hours of each tide, and discharged into the river at high water at the top of the ebb. This reservoir is situate on the east side of the sewer, and immediately adjacent to the river bank.

The new works consist of covered precipitation tanks adjacent to this reservoir on its north side, and occupying the ground between the outfall sewer and Barking Creek, an area of between 10 and 11 acres. There will be thirteen of such tanks, each 31 feet 6 inches wide, and averaging about 1,000 feet long. Communications will be made between the outfall sewer and each of these tanks, each fitted with two penstocks, so that communication may be opened or shut off at pleasure.

The sewage will be admitted into each of the tanks in succession, and after being allowed to remain quiescent for a sufficient time to admit of the deposit of the solids in the sewage, the precipitation of which will be expedited by the admixture of 3·7 grains of lime and 1 grain of proto-sulphate of iron per gallon, the effluent will be run off over a weir, which will fall as the water in the tank lowers, so that the top film of the effluent only will be taken off, and the tank emptied gradually, so as to prevent any disturbance of the solids by the operation.

The effluent, after flowing over the weirs (of which there will be ten in each tank), will pass into culverts carried transversely under the tanks and extended, some into the compartments of the existing reservoir, and some into a chamber under the outfall sewer through which, at present, the sewage is discharged into the river from the existing reservoirs. When the level of the tide will admit, the effluent will be discharged through this chamber direct into the river; but when the water in the river is too high to admit of this, the effluent will be conveyed by the other culverts into the several compartments of the present reservoir, and stored there until the level of the water in the river will admit of its discharge.

When each compartment is emptied of the effluent the sludge, which will be in a semi-liquid state, will be discharged through culverts passing under the outfall sewers into a collecting culvert, from which it will be conveyed by pipes into a receiving well or sump, and pumped into a series of twelve tanks placed side by side, and situate between the outfall sewer and the river. These tanks will each be 20 feet wide and 140 feet long, will cover an area of over an acre and a half, and, like the precipitation tanks, will be covered so as to prevent nuisance. The sludge will be allowed to remain quiescent in them, to allow of a further precipitation, and the effluent water will be discharged over weirs into a culvert which will convey it into a store under the tanks, from whence it will be lifted and discharged through pipes to the liming station, there to be mixed with lime which is used for precipitation. The settled sludge remaining after this further precipitation will be discharged through culverts into a sludge store situate under the tanks, and will be lifted thence and conveyed by pipes along a jetty, and to a landing stage to be erected in the river, and there discharged into ships which will convey the sludge to sea. In the event of the ships being detained by stress of weather, there is a further store for sludge at a lower level extending under the whole of the area occupied by the upper stores.

On the north side of these sludge settling tanks will be erected engine and boiler houses and work shops in connection, to contain engines and machinery for lifting the sludge into the settling tanks, and the settled sludge into the ships, as well as for pumping the sludge effluent to the liming station.

The lime for assisting the precipitation of the solids of the sewage is introduced into the outfall sewers at a point about 700 yards, and the proto-sulphate of iron about 530 yards above the precipitation channels. The liming station will comprise a lime store, floors for slaking the lime, and six tanks for mixing the slaked lime with the effluent water from the sludge settling tanks, or with sewage taken direct from the outfall sewers; an elevated lime water tank or reservoir built above the lime store, and into which the lime water will be lifted by pumps, for which machinery and the requisite engine and boiler houses will be erected adjacent to the lime stores. From this elevated tank the lime water will be conveyed to and injected into the sewage passing along the outfall sewers, through cast iron injectors placed in the sewers. There will be means of turning the lime water into any one of the three lines of sewers and of regulating the supply by means of sluice valves fitted to the pipes leading to the injectors. The injectors consist of cast iron chambers 4 feet 6 inches in length, 6 inches wide, and 6 feet in height, fitted with a number of nozzles, through which the lime water will be injected and mixed with the sewage as it flows past.

The iron water station comprises timber sheds for storing the proto-sulphate of iron, a mixing shed in which the iron will be crushed and mixed with water, an engine shed to contain engines and machinery for crushing the iron and mixing it with water, as well as for raising water for boilers and into mixing tanks. The iron water will be conveyed by stone ware pipes, carried underground and along the top of the outfall sewer into a service tank, from which it will be carried by pipes into each of the three outfall sewers, and injected into the sewage through perforations in a pipe fixed vertically in each of the sewers. As with the lime water, there will be appliances for regulating the supply of iron water to each of the sewers, to meet the varying requirements of the discharge.

There will be a large settling pond, covering an area of 1¼ acres, situate near the river, divided into six compartments, each 60 feet by 60 feet, and about 7 feet deep, into which water will be received from the river and allowed to settle; the clear water being afterward filtered and used for the supply of the several boilers, for slaking the lime, and for mixing with the proto-sulphate of iron.

The jetty, which will extend 576 feet into the river from the present river bank, will be 15 feet wide, and will be a timber structure supported upon piles. At the river end of the jetty will be a timber landing stage 300 feet in length and 20 feet wide.

The iron pipes for conveying the sludge to the ships will be carried under the platform, and will be furnished at the end with a delivery pipe, socketed to admit of a vertical movement, so as to discharge the sludge into the ship at varying levels of the tide. A tramway will be laid along the full length of the jetty connecting it with the whole of the works.

The contract for the works includes the erection of twelve cottages and a residence for the superintendent, and the diversion of the Old Galleons sluice and ditch, which is one of the main sewers under the jurisdiction of the Essex commissioners of sewers. There will be a large quantity of surplus earth from the excavations which will be used in forming the banks for the tramways, and in raising the general level of the ground, which is now 6 or 7 feet below the level of Trinity high water. The works extend over an area of about 50 acres, the quantity of sewage to be dealt with will amount to about 90,000,000 gallons per day, and the quantity of lime to be used in precipitation to 23 tons per day.

Two contracts have been entered into for the execution of the works—one with Messrs. Mowlem & Co., for the general work, for 406,000*l*., and the other with the Glenfield Company, of Kilmarnock, for engines and machinery, for 42,567*l*.—*The Architect*.

[SCIENCE.]

THE HEMENWAY-CUSHING EXPEDITION.

MR. FRANK H. CUSHING, whose wonderful discoveries in regard to the customs and religion of the Zuni Indians, made during his residence among this remarkable people, are recognized as the most valuable of recent additions to American ethnologic knowledge, has spent the past winter and spring, as may be known to many readers of *Science*, in Arizona, making explorations of extensive ancient ruins there. The expenses of this expedition, which is well equipped, are paid by Mrs. Hemenway of Boston, the lady who has lately shown such substantial interest in Mr. Cushing's work. That gentleman had reached a point in his studies of the Zunis that, in order to pursue them further, it seemed necessary to attempt to trace their history back to the beginning by an examination of the ruined cities and temples in which their ancestors lived and worshiped. This is the object of Mr. Cushing's recent work. Attached to this expedition, during the past winter and spring, was Dr. James L. Wortman, of the Army Medical Museum, who has recently returned to Washington. His mission was chiefly that of an anatomist engaged in anthropological work. The medical museum has been engaged for several years in the collection of human skeletons for the purposes of comparison, and the net result of Dr. Wortman's labors during the past winter and spring has been the securing of about one hundred complete skeletons, the skulls of which are in a good state of preservation, although the rest of the bones are more or less imperfect. The following brief description has been made up from an interview with Dr. Wortman.

The scene of Mr. Cushing's explorations is the wide valley or plain at the confluence of the Salt and Gila rivers in Southwestern Arizona. To-day railroads cross this valley, and much of it has been reclaimed by irrigation from the desert condition into which it relapsed when the ancient inhabitants disappeared. Still a wide expanse of the plain, which is forty-five miles across, remains a desert covered with sage brush, cactus, and mesquite. It slopes from the Salt to the Gila river, and advantage was taken of this feature of its topography by the ancient people in constructing canals to irrigate the whole plain. In some places these old canals have been reopened by the modern farmers, and restored to their original use. On this wide plain are many groups of mounds, in excavating which Mr. Cushing has discovered many ancient cities, to some of which he has given the names of Los Muertos, Los Hornos, Los Guanacas, Los Pueblitas, Los Acequias, etc. Los Muertos, the city of the dead, has been traced for three or four miles, and forty or fifty huge structures or communal houses in it have been examined.

In the ruins of these structures, Dr. Wortman says, the greater part of the specimens have been found. The houses are rather large, 300 or 400 feet long and 200 feet wide, possibly larger. They were generally built of adobe bricks, sun dried, without straw or mixture of cement of any kind. In some instances, Mr. Cushing thinks, they were four or five stories high, but this can only be conjectured from the size of the mounds, the thickness of the walls, and the quantity of the *debris*. All that now remain are the foundation walls, and around and within them the *debris*. These houses seem to have been constructed on the same plan as the pueblos of the Zunis, the Moquis, and other existing pueblos. In Casa Grande a cement is found to have been used on the outside and inside of the structure. The builders were probably acquainted, as the Aztecs were, with some sort of cement, which they used to protect their structure from the weather. In some instances it was found that instead of building with adobe bricks, upright posts had been set up. The space between was wattled with cane or willow, and then filled with adobe. The woodwork has entirely disappeared, there being nothing left of it except occasional bits of charred wood. The post holes are still there, and show the manner of construction.

The dead were buried in the houses. Below the floor of the house a vault was dug, and the body, first wrapped in cloths of some description, was deposited in this sepulcher. Then the grave was filled with adobe, which was packed around the body. Food vessels and water jars were also buried with the dead. With the body of a man of consequence, war clubs, images of various kinds, arrows, and other articles were also interred, but, of course, only the most imperishable remain. Sometimes two or three bodies have been found in the same sepulcher, and it is believed that where two are found in one grave they were man and wife. The skeletons are not well preserved, and crumble after a few hours' exposure to the air. The bodies were wrapped in cotton cloths, as is shown by the impressions left in the adobe, or mud, which was soft when it was first packed around them. In some instances the fragments of cloth have been found. It is rather fine texture, and the size of the cavities in which the skeletons are now found proves that the bodies must have been wrapped thickly, so that little or no moisture had access to them. Such being the case, the condition of the bones, especially when the dryness of the climate of Arizona is considered, indicates a great antiquity for these burial places.

The tombs already described seem to have been those of the priestly class. The bodies of the common people were cremated. In connection with each house supposed by Mr. Cushing to be the house of a clan or one of the sociological divisions, such as are found among the Pueblo Indians, was what the explorer calls a pyral mound. On this the bodies and effects of the dead were consigned to fire. This mound is eight to ten feet high, and is composed entirely of the accumulations or *debris* resulting from these cremations. The ashes and charred bones of each body were collected and placed in an urn, which was buried at the foot of the mound from six inches to a foot below the surface. In some instances as many as 400 or 500 of these urns were found buried about a mound.

Between forty and fifty of the large, or communal, houses were found in Los Muertos. In the center was a structure larger than the others, which Mr. Cushing called a temple. In this building, which was inclosed by a strong adobe wall, and in no other, were bodies found deposited in an upper story. Here there were four or five adobe sarcophagi, two of which were placed nearer the center of the building than the others, were more conspicuous, and contained what appeared from the skeletons to be the remains of men of advanced age. Mr. Cushing said that extra decorations were found on these two sarcophagi. It is supposed that this was the home of the chief ruler of the tribe, the chief priest, or some one of exceptional note. The object of the wall surrounding the structure was probably to make it a stronghold or citadel in time of war. The temple might also have served as a general store house for provisions.

This ancient people built all their houses on the main line of the irrigating canal. This irrigating system was extensive. The many ditches and canals were constructed on a peculiar plan. A cross section shows a series of terraces. At the bottom is a central ditch, and above this, widening to the top, are terraces. The large canals are about twenty-five feet wide at the top, the central ditch being four or five feet wide. Mr. Cushing believes the canals were used not only for irrigation, but for navigation as well. "We know," said Dr. Wortman, "that the inhabitants of these towns used timbers of considerable size in their building operations. The only available wood in the immediate vicinity was cottonwood or mesquite, which would not serve their purpose. They used pine, and the nearest point where they could get lumber of that description from was seventy-five or a hundred miles away. Timbers of a size required by them in the construction of their buildings could not be carried such a distance on the backs of men. The conclusion is that they floated them down the Gila or Salt river. Certain remains have been found indicating that they constructed of reeds rafts (or balsas) such as are found in Mexico and the South Sea Islands. Stones of considerable size, not found on the plains, were taken to the towns from the mountains. It would have been impracticable to have carried these stones such a distance unless they were floated on rafts.

"To conduct water from one level to another in these canals was a gigantic undertaking, especially when the character of the implements used is considered. They had no tools except stone ones in making their excavations. A few copper implements were found, but metal was scarce. Copper was used for ornaments, earrings, and bells. There was not enough, it is supposed, to use for agricultural implements. The irrigating system is sufficient in extent to render the whole extensive valley fertile. The beds of the canals were puddled. Soft mud was packed down well, and then burned or baked by filling the canal with brush and setting fire to it. When constructed this way the lining was almost as hard and impervious to water as terra-cotta pipes. They lost but little water, and the people were extremely economical of water. In some places large ditches terminated in great reservoirs. In these probably water was stored to be used in times of drought. The longest irrigating ditch was probably about twenty-five miles long. The river has perceptibly gone down in its bed since water was taken from it to fill these canals."

The theory that these towns were occupied successively is disproved, Dr. Wortman thinks, by the fact that some towns are twenty-five miles from the river, and all the intervening space is covered with ruins. Canals were constructed from the river to the furthermost town. If the towns were successively occupied, there would have been no necessity for constructing these irrigating canals. The enormous labor expended with stone picks for excavating and baskets for carrying away dirt in extending these irrigating ditches to these distant points indicates plainly that all the land between them and the river was occupied.

Mr. Cushing's party found on the rocks of neighboring mountains petrographs, or crude etchings. All illustrated matters of a realistic nature, and did not record the history of an individual or of a nation. They represented men offering prayers for rain, or herders or hunters offering sacrifices. These rock pictures are interesting, however, as bearing upon the question of the use of domestic animals by these people, and their probable acquaintance with the use of wool. In these petrographs appear representations of animals much like the llama of South America. They are represented in a position or attitude that the llama habitually assumes. They are so pictured as to lead to the conclusion that they were domestic animals. They are connected with a string or cord, a man having hold of the string and appearing to be driving them.

Mr. Cushing has also found in the ruins a number of terra cotta figures, representing various animals that were hunted—the mountain sheep, the deer, the fox, the coyote. In one case a number of figures of animals corresponding in appearance with those pictured were found buried together. Mr. Cushing came to the conclusion that these were a herder's sacrifice. Instead of sacrificing the animals themselves he substituted the images. The animal represented undoubtedly resembles the llama. It is quite different from the mountain sheep or any other animal corresponding in size, and has a long neck. If it is true that they possessed a domestic animal of this species, either the people were of very great antiquity or there was a species of llama in North America at a much more recent date than scientific men suppose. It is a matter, too, of extraordinary interest and significance, if these people had the same domestic animal as that found among the Peruvians when the Spaniards first came to this country. If they had such a domestic animal, they undoubtedly took its fleece for clothing, and had woolen as well as cotton fabrics. Some of the earlier Spanish explorers speak of woolen cloth in the possession of the Pueblo Indians. If there is truth in that, then it is more than probable that these people possessed a domestic animal of the llama species probably as large as a good-sized sheep.

These people had access to the Gulf of California. This is proved by the discovery of shells in the ruins which have been identified as belonging to the Pacific coast. Though at a considerable distance, they probably had communication with the sea coast and obtained shells by bartering with other Indians. Of some of these shells skillfully carved ornaments are made. Mr. Cushing found a frog carved from a shell, the back being inlaid with turquoise. The inlaying had been done by cutting little square holes in the shell and fitting pieces of turquoise to them. A native species of lac was used in cementing the pieces. This lac was used also in basket work. They made carved bracelets, earrings, and finger rings, and various ornaments inlaid in the manner described.

The petrographs did not throw much light on the manner of dress that prevailed, as they showed only the costume worn at certain ceremonials—a long gown extending down almost to the feet. Near the skeleton of an old war chief was found a fragment of a gown that must have been richly embroidered in various colors. It was badly decayed, but there was enough left to show that it was an embroidered garment.

"The antiquity of these ruins is not settled," said Dr. Wortman. "It has been maintained by respectable authorities that these ruins were occupied within the historic period. I don't think that can be possible. Historic evidence is decidedly against it. We have some records of the earliest Spanish explorers bearing on that point." Dr. Wortman stopped here briefly to summarize the history of the explorations of Cabesa de Vaca, prior to 1530, and of his immediate successors, Father Nisa and Coronado. Coronado's route, he said, to Casa Grande, could be easily traced. There he found the ruin now standing, and gave a description of it by which it could be recognized to-day. "If it be true," said the doctor, "that Casa Grande, or Chichilliecato, the Red House, a ruin still standing three stories high, twenty-five or thirty miles from Los Muertos, was in ruins when the Spaniards came there, as the records of Coronado's expedition in 1540 plainly indicate, assuredly these houses that Mr. Cushing is excavating, now practically leveled to the ground, had disappeared long prior to that period. In all the excavations Mr. Cushing has made, in the thousands of specimens collected, not a single specimen has been found that would give evidence of contact with whites. My own opinion is that the ruins are pre-Columbian, and if I were going to give a guess I would say they are not less than a thousand years old. The size of the mesquite trees growing from the mounds indicates a great age.

"Considering all the evidence," said Dr. Wortman, "I have no doubt that when these ruined towns were inhabited, this valley, many miles in extent, was a fertile region, occupied by a thrifty people. They raised cotton, corn, and tobacco. Fragments of cotton have been dug up, tobacco has been found in their sacred cigarettes, and charred corn cobs also remain to give evidence as to the agricultural products of the valley. As to the population, allowing even a greater number of acres to the man than is now cultivated by the Pima Indians, who, besides supplying their own wants, raise a large quantity of wheat to sell, allowing say from five to eight acres to a man, the population of the valley must have been at least 200,000, if, as I believe, all their towns were simultaneously occupied. There are evidences that the Zunis of to-day are a remnant of these people.

"The osteology of the people has not yet been thoroughly studied. The skeletons collected will be compared here at the Medical Museum, and the careful study of them will undoubtedly throw much light on the relations of these people to historic people. The heads were short, or, in other words, the people were brachy-cephalic. They were small in stature. The general indications are that they are related to the Zunis, and they are not unlike the Aztecs and Peruvians. Among the skulls I have found frequently the Inca bone or *Os Inca*, the extra bone in the back part of the skull, which received its name because it was a common thing among the Incas. These indications, with other evdences, suggest many interesting inquiries. It may have been that from this ancient civilization sprang that of Central America and of the Peruvians. A portion of the people may have migrated south, taking the llama with them, while others went north and founded the later Pueblo civilizations."

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TABLE OF CONTENTS.

PAGE

I. BIOGRAPHY.—The Elder Statue.—Biographical note of the great ship builder JOHN ELDER, and description of the recently erected statue.—1 illustration. 10565

II. CHEMISTRY.—How to Analyze Iron and Steel.—A full description of the chemical processes employed.—1 illustration. 10565

III. CIVIL ENGINEERING.—Timber and Some of its Diseases.—By H. MARSHALL WARD.—Continuation of this important treatise; how the attacks of insects upon the leaves may affect the wood. 10565

IV. ELECTRICITY.—Electrolysis by Alternate Currents.—Notes of a curious investigation of the paradoxical action of alternating currents. 10565
On the Proper Size of Telephone Conductors.—By DAVID BROOKS.—A plea for the use of small conductors, with reasons for the practice. 10565
The Mechanism of Electrolysis by Alternating Currents.—Further account of the investigation into the generation of gases by this class of currents. 10565

V. ETHNOLOGY.—The Hemenway-Cushing Expedition.—Remarkable discoveries by Mr. FRANK H. CUSHING in Arizona in the ethnology of ancient America. 10565

VI. GEOLOGY.—Geology.—By ARCHIBALD GEIKIE, LL.D., F.R.S.—The movements of the crust of the earth considered; continuation of this interesting treatise.—11 illustrations. 10565

VII. MECHANICAL ENGINEERING.—Advice to Young Mechanical Engineers.—Professor Perry's address to his students at the Finsbury Technical College.—A valuable paper for all working engineers.—1 illustration. 10567
Copper Steam Pipes for Modern High Pressure Engines.—By W. PARKER.—Investigation into the cause of explosions of copper steam pipes with brazed joints, and tests of electrically deposited pipes, with account of the process of manufacture of the latter. 10567
Double Action Steam Pile Driver.—A new type of reciprocating ram, receiving steam through the piston rod. 10567
Efficiency of Plant.—By Prof. DE VOLSON WOOD.—A review of recent steam engine efficiency. 10567
Engines of the Re Umberto.—Twin engines, each of 10,000 horse power, illustrated.—1 illustration. 10567
The Darby Broadside Steam Digger.—A remarkable agricultural engine, substituting digging for plowing.—Its full dimensions and data.—1 illustration. 10567

VIII. MISCELLANEOUS.—Curious Inventions.—Aneroid barometer, electric paper weight, lamp shade with moving disks, and musical paper cutter.—Four objects of much interest described and illustrated.—4 illustrations. 10567
The True Relation of Physical Science to Religion.—By HENRY MORTON, President Stevens Institute.—A concise examination of this vexed question. 10567

IX. NAVAL ENGINEERING.—Mechanically Propelled Boats.—Some novel ideas in the direction of lifeboats and steamships.—The work of a woman inventor.—3 illustrations. 10565

X. ORDNANCE.—Russian and English Field and Coast Guns.—A review of the Russian field guns from an English standpoint, with full sections and elevations of Russian guns.—16 illustrations. 10565

XI. SANITATION.—London Sewage.—New sewage precipitation works recently erected for treating a portion of the London sewage. 10565

XII. TECHNOLOGY.—To Mend Broken Marble.—A cement for this purpose made of plaster of Paris and alum. 10565
Wood Wool Making Machine.—Machine for making this product, with some notes on the article itself and its uses.—5 illustrations. 10565

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